U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-252 963

Water Pollution Control in the Carbon and Alloy Steel Industries

Datagraphics, Inc.

Prepared For
Industrial Environmental Research Lab.

April 1976

KEEP UP TO DATE

Between the time you ordered this report—which is only one of the hundreds of thousands in the NTIS information collection available to you—and the time you are reading this message, several *new* reports relevant to your interests probably have entered the collection.

Subscribe to the **Weekly Government Abstracts** series that will bring you summaries of new reports *as soon as they are received by NTIS* from the originators of the research. The WGA's are an NTIS weekly newsletter service covering the most recent research findings in 25 areas of industrial, technological, and sociological interest—invaluable information for executives and professionals who must keep up to date.

The executive and professional information service provided by NTIS in the **Weekly Government Abstracts** newsletters will give you thorough and comprehensive coverage of government-conducted or sponsored research activities. And you'll get this important information within two weeks of the time it's released by originating agencies.

WGA newsletters are computer produced and electronically photocomposed to slash the time gap between the release of a report and its availability. You can learn about technical innovations immediately—and use them in the most meaningful and productive ways possible for your organization. Please request NTIS-PR-205/PCW for more information.

The weekly newsletter series will keep you current. But *learn what you have missed in the past* by ordering a computer **NTISearch** of all the research reports in your area of interest, dating as far back as 1964, if you wish. Please request NTIS-PR-186/PCN for more information.

WRITE: Managing Editor
5285 Port Royal Road
Springfield, VA 22161

Keep Up To Date With SRIM

SRIM (Selected Research in Microfiche) provides you with regular, automatic distribution of the complete texts of NTIS research reports *only* in the subject areas you select. SRIM covers almost all Government research reports by subject area and/or the originating Federal or local government agency. You may subscribe by any category or subcategory of our WGA **(Weekly Government Abstracts)** or **Government Reports Announcements and Index** categories, or to the reports issued by a particular agency such as the Department of Defense, Federal Energy Administration, or Environmental Protection Agency. Other options that will give you greater selectivity are available on request.

The cost of SRIM service is only 45¢ domestic (60¢ foreign) for each complete microfiched report. Your SRIM service begins as soon as your order is received and processed and you will receive biweekly shipments thereafter. If you wish, your service will be backdated to furnish you microfiche of reports issued earlier.

Because of contractual arrangements with several Special Technology Groups, not all NTIS reports are distributed in the SRIM program. You will receive a notice in your microfiche shipments identifying the exceptionally priced reports not available through SRIM.

A deposit account with NTIS is required before this service can be initiated. If you have specific questions concerning this service, please call (703) 451-1558, or write NTIS, attention SRIM Product Manager.

This information product distributed by

NTIS U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

146119

EPA/600/2-76/193

PB 252 963

Final Report

WATER POLLUTION CONTROL IN THE CARBON AND ALLOY STEEL INDUSTRIES

by

Henry C. Bramer, Ph.D.
Datagraphics, Inc.
101 West Mall Plaza
Carnegie, Pa. 15106

Project R800625
Program Element 1BB036

Project Officer

Hugh B. Durham, Ph.D.
Heavy Industrial Sources Branch
Cincinnati, Ohio.

Prepared for

Office of Research & Development
Washington, D.C. 20460

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET	1. Report No. EPA/600/2-76/193	2.	3. Recipient's Accession No. PB-252 963

4. Title and Subtitle
Water Pollution Control in the Carbon and Alloy Steel Industries

5. Report Date
April 1976

6.

7. Author(s)
Bramer, Henry C.

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Datagraphics, Inc.
101 West Mall Plaza
Carnege, Pennsylvania 15106

10. Project/Task/Work Unit No.

11. Contract/Grant No.
S 800625

12. Sponsoring Organization Name and Address
Industrial Environmental Research Lab., Cincinnati, Ohio. Heavy Industrial Sources Branch.

13. Type of Report & Period Covered
Final Report
June 1972 - May 1973

14.

15. Supplementary Notes

16. Abstracts

This report provides information relative to water pollution control practices in the carbon and alloy steel industries. The scope of information includes brief descriptions of the wastewater producing processes, detailed analysis of the raw wasteloads, identification of wastewater treatment methods, cost of treatment methods and an inventory of the steel industry.

Coverage of steel industry activities includes coke plant operations, blast furnace systems, sinter plants, steelmaking facilities, various hot forming mills, pickling, cold reduction and plating technology. In many cases, generalized illustrations are utilized to describe typical industry situations.

Portions of this document are not fully legible

17. Key Words and Document Analysis. 17a. Descriptors

steel industry

water pollution

steel plants

carbon steel industry

alloy steel industry

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

PRICES SUBJECT TO CHANGE

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 274
	20. Security Class (This Page UNCLASSIFIED	22. Price 9.00-2.25

i.

ATTENTION

AS NOTED IN THE NTIS ANNOUNCEMENT, PORTIONS OF THIS REPORT ARE NOT LEGIBLE. HOWEVER, IT IS THE BEST REPRODUCTION AVAILABLE FROM THE COPY SENT TO NTIS.

EPA REVIEW NOTICE

This report has been reviewed by the Office of Research and Monitoring, Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

TABLE OF CONTENTS

I. COKE PLANT OPERATIONS 1
- Coke Plant Production 14
- Coke Plant Waste Water Data 20
- Total Effluent Raw Waste Loads 28
- Ammonia Liquor Raw Waste Loads 37
- Ammonia Still Raw Waste Loads 42
- Final Cooler Raw Waste Loads 46
- Benzol Plant Raw Waste Loads 48
- Raw Waste Loads - Summary Data 50
- Cost of Waste Treatment Methods 72
- Coke Quenching with Wastewater 75
- Waste Water Treatment Methods 78

II. BLAST FURNACE OPERATIONS 80
- Sinter Plants 109
- Ferromanganese Blast Furnaces 111
- Blast Furnace & Sinter Plant Treatment Costs 112

III. STEELMAKING OPERATIONS 115
- Open Hearth Furnaces 117
- Basic Oxygen Furnaces 123
- Electric-Arc Furnaces 125
- Q-Basic Oxygen Process 129
- Vacuum Degassing 129
- Teeming 130
- Continuous Casting 131
- Slag Handling 132
- Oxygen Generating 132
- Steelmaking Production Facilities 138
- Wastewater Treatment Methods and Waste Loads 157
- Steelmaking Treatment Costs 169

IV. HOT ROLLING MILLS 173
- Secondary Mills - Finished Products 175
- Sheet and Strip 176
- Bar Products 177
- Plate Mills 178
- Structural Shapes 179
- Pipe and Tubing 180
- Waste Loads from Hot-Rolling Operations 185
- Mini-Steel Plant 196
- Costs of Wastewater Treatment Methods 202

TABLE OF CONTENTS (CONTINUED

V. PICKLING 219
- Carbon Steel Pickling 221
- Raw Waste Loads - Hydrochloric Pickling 223
- Alloy and Stainless Steel Pickling 225
- HNO_3 - HF Pickling 227
- HCL Pickling 228
- H_2SO_4 Pickling 229
- Pickling Wastes Treatment Methods 231
- Waste Treatment For Pickling Wastewaters 233
- Neutralization 235
- Regeneration of Spent Liquor 238

VI. COLD REDUCTION 242
- Treatment of Cold-Mill Wastewater 243
- Various Types of Roll Coolants 244
- Cold Reduction Raw Waste Loads 245
- Temper and Skin Pass Mills 251

VII. PLATING
- Electrolytic Tin Plating 252
- Chrome Plated Steel 254
- Detinning Facilities 258
- Galvanizing

FIGURES

1. Typical Coke Plant Production Processes 2
2. Phenol in Ammonia Liquor as a function of Coke Temperatures 52
3. BOD vs COD for Various Coke Plant Waste Waters 53
4. Distribution of Coke Ovens By State 54
5. Type 1 Coke Plant Operations 63
6. Type 2 Coke Plant Operations 64
7. Type 3 Coke Plant Operations 65
8. Type 4 Coke Plant Operations 66
9. Type 5 Coke Plant Operations 67
10. Type 6 Coke Plant Operations 68
11. Type 7 Coke Plant Operations 69
12. Type 8 Coke Plant Operations 70
13. Type 9 Coke Plant Operations 71
14. Schematic Diagram of a Coke Quenching System for Disposing of all Liquid Wastes 76
15. Blast Furnaces - Less the 30 ft. Diameter Hearth 88
16. Blast Furnaces - 30-38 ft. Diameter Hearth 89
17. Raw Steel Production By Type of Furnace 119
18. Raw Steel Production By Type of Furnace and Grade-1971 120
19. Process Flow Diagram - Steelmaking 134
20. Steeling Rate Curves of Untreated Samples from BOP Thickener Influent 165
21. Electric Furnace Gas Cleaning System 170
22. Schematic Diagram of Polymenr and Magnetic Flocculation of Basic Oxygen Furnace Wastewater 171
23. Schematic Diagram of Interlake Steel Corporations Integrated Air-Water Waste Treatment System for the Basic Oxygen Furnace Shop 172
24. Sedimentation Index Curves 194
25. Examples of Alternative Methods of Disposing of Spent Pickle Liquor 232
26. Five Stand Tandem Cold Mill - Armco Steel Corporation Ashland, Kentucky 248
27. Production Stages of a Tin Free Steel - Chrome Plate Line 256

TABLES

I	Coke Plant Production Data	15
II	Coke Plant Production Capacities	17-A
III	Coke Plant Waste Water Data	21-24
IV	Coke Plant - Total Plant Effluent	25
V	Coke Plant - Ammonia Liquor	26
VI	Coke Plant - Ammonia Still Wastes	27
VII	Raw Waste Loads - Summary Data	51
VIII	Distribution of Blast Furnaces by State	84
IX	Blast Furnace Production From Published Sources	87
X	Blast Furnaces in the United States - 1970	91-102
XI	Blast Furnace Waste Water DATA	105
XII	Raw Steel Production by Type of Furnace	118
XIII	Electric-Arc Furnace Production by Grade of Steel	128
XIV	Basic Oxygen Steelmaking Plants in the United States	135-136
XV	Electric Furnace Production DATA	137
XVI	Steelmaking Furnaces in the United States	140-155
XVII	Continuous Casting Plants in the United States	156
XVIII	Steel Making Waste Loads	162
XIX	Steel Manufacturing - Continuous Casting Effluent, Standard Raw Waste Load	163
XX	Steel Manufacturing - Vacuum Degassing Effluent, Standard Raw Waste Load	164
XXI	Net Shipments of Steel Products - 1962-71	181
XXII	Raw Steel Production vs. Net Shipments of Steel Products - 1962-71	182
XXIII	Shipments of Steel Products by Grade - 1971	183-184
XXIV	Water Use Rates Reported for Specific Rolling Mills	188
XXV	Water Uses in Hot-Rolling Mills (Gals. per ton of rolled products)	189
XXVI	Summary of Hot-Rolling Water Uses	190
XXVII	Steelmaking, Casting, Rolling, Capacity at Mini-Steel Plants	197-198
XXVIII	Water and Air Facilities at Mini-Steel Plants	199-201
XXIX	Rolling Mill Facilities and Daily Capacity	205-218
XXX	Treated Pickling Effluent Waste Loads	241

COKE PLANT OPERATIONS

Coke plants are operated as parts of integrated steel mills to supply the coke necessary for the production of pig iron in blast furnaces. Nearly all coke plants today are by-product plants, i.e., products such as coke oven gas, coal tar, crude and refined light oils, ammonium sulfate, anhydrous ammonia, ammonia liquor, and naphthalene are produced in addition to coke. Economic factors, particularly competition from the petrochemical industry, have changed the traditional coke plant operation. Tar and coke oven gas remain valuable by-products, the former for sale and the latter for internal use. Light oil production, particularly refined products, and ammonium sulfate production are not usually profitable. The production of sodium phenolate is probably never profitable.

The flow diagram of Figure 1 shows a typical by-product coke plant operation

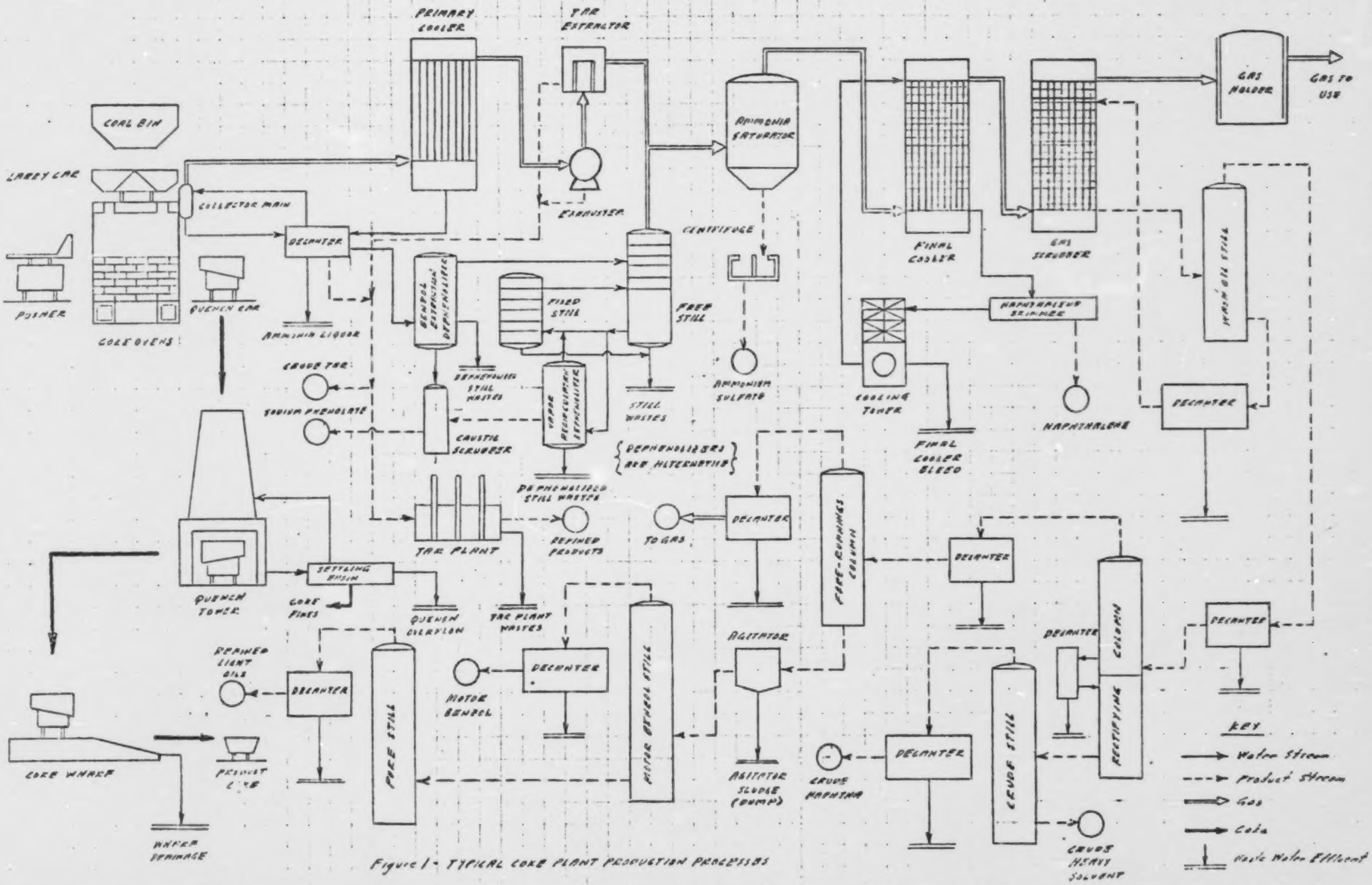


Figure 1 - TYPICAL COKE PLANT PRODUCTION PROCESSES

A by-product coke plant consists essentially of the ovens in which bituminous coal is heated, out of contact with air, to drive off the volatile components. The residue remaining in the ovens is coke; the volatile components are recovered and processed in the by-product plant to produce tar, light oils, and other materials of potential value, including coke oven gas.

Each coke oven is a narrow chamber made of silica brick, typically 18 inches wide, 15 feet high, and 40 feet long, arranged side by side in groups of 30 or more, each group called a battery. The ovens are heated by burning coke oven gas in flues between the side walls of the adjacent ovens. About 40 percent of the gas produced by the coking process is used to heat the coke ovens; the remaining gas is used as a fuel in other mill operations.

Coal is charged through holes into the tops of the ovens from hopper bottom cars which run on tracks over the top of the battery. During the 17 to 20 hour coking period, the gases and volatile materials distilled from the coal escape through the ascension pipes on the top of the ovens and pass into the collection main which runs the length of the battery. At the end of the coking period, the doors are removed from each end of an oven and the pushing machine pushes the red hot coke into the quenching car. The quenching car moves to the quenching tower where the coke is cooled by water sprays, and the cooled coke is delivered to handling equipment for subsequent use. Much of the quench water is evaporated in the quench tower. The remainder flows to a settling basin where fine coke particles settle our and are periodically removed. The clarified water is recycled to the quenching tower. The settling basin may overflow if an excess of water is in the system, resulting in a source of wastewater.

In the collection main, the gas produced by the coking process is cooled with water sprays, the water being known as flushing liquor. The cooling condenses out most of the tar in the gas and the liquor, mixed with tar, flows to a decanter where the tar is separated and recovered. The gas then passes through the primary coolers where most of the moisture is condensed, the condensed liquid flowing to the tar decanter where it is mixed with the flushing liquor being recirculated to the collector main sprays. The excess ammonia liquor (flushing liquor or decanter liquor) is thus produced in the coking process, used to cool the gas in the collector main and to flush the main clean, and must eventually be discarded. The ammonia liquor is the major source of wastewater in most plants.

Following the primary coolers, the gas passes through the exhausters which draw the gas under suction from the collection main and force it under pressure through the by-product plant equipment. The gas then passes through tar extractors where the remaining tar and some additional ammonia liquor are separated and returned to the tar decanter. The ammonia absorber conventionally follows the tar extractor; the ammonia absorber and the ammonia still are discussed later along with dephenolizers. The tar is either sold as the crude product or is further refined.

Following the ammonia absorber, the gas passes through the final coolers in which water sprays dissolve soluble constituents and flush out the insoluble naphthalene which is condensed at this point. The water flows to the naphthalene sump where the naphthalene is recovered by skimming and then to a cooling tower for recirculation through the final cooler. A properly designed closed recirculation system should have little or no discharged wastewater here, since the cooling tower evaporation balances the moisture condensation from the gas. When other than a closed system is used, final cooler water can be the largest source of contaminated wastewater.

From the final coolers, the gas passes through the gas scrubbers in which the crude light oils are removed by an absorbent generally known as wash oil. The crude light oils contain the materials which are further separated and recovered in the by-product plant. The gas then goes to a gas holder for use in underfiring the coke ovens and a booster pump which sends it to the other mill uses.

Following the gas scrubbers, the light oils are stripped from the wash oil absorbent by steam distillation; the wash oil is cooled and recirculated to the gas scrubbers. The vapors leaving the wash oil still are condensed in the light oil condenser and then flow to the light oil decanter where the light oil and condensed water are separated. Indirect cooling is generally used in the wash oil cooler and light oil condenser and no wastewaters are produced. The water separated from the light oil in the decanter is a major source of wastewater.

In the indirect ammonia recovery process, a portion of the ammonia is dissolved in the flushing liquor. Additional ammonia is scrubbed from the gas with water. An ammonia still is used to concentrate the ammonia liquor for sale in this form.

In the semi-direct ammonia recovery process, the ammonia absorber, or saturator, follows the tar extractor. Here the gas passes through a dilute sulfuric acid solution in a closed system from which ammonium sulfate is crystallized and dried for sale. The ammonia still receives the excess ammonia liquor from which ammonia and other volatile compounds are steam distilled. From the free leg of the ammonia still ammonia, hydrogen sulfide, carbon dioxide, and hydrogen cyanide are steam distilled and returned to the gas stream. Milk of lime is added to the fixed leg of the ammonia still to decompose ammonium salts; the liberated ammonia is steam distilled and also returned to the gas stream. The ammonia liberated in the ammonia still is recovered from the gas as additional ammonia sulfate in the saturators.

Dephenolizers remove phenol from the ammonia liquor and recover it as sodium phenolate. In the liquid extraction process the ammonia liquor is mixed with benzol or light oil which extracts the phenol. The phenol is then extracted from the light oil with a caustic solution, forming sodium phenolate. The oil is recycled to the process and the dephenolized ammonia liquor goes to the ammonia still. In the vapor recirculation process, steam is used to vaporize the phenol in the ammonia liquor leaving the free leg of the ammonia still. The steam and vapors are scrubbed with a caustic solution which converts the phenol to sodium phenolate. The steam is reused and the dephenolized liquor is returned to the fixed leg of the still.

The coke oven gas is sometimes further purified following the light oil scrubbers to remove hydrogen sulfide. The carbonate process is sometimes used to recover elemental sulfur for sale. Some plants employ no ammonia stills or saturators. The Keystone recovers anhydrous ammonia through absorption in a recycled solution of ammonium phosphate. In a typical absorption cycle, lean 40% phosphate solution is then reboiled in a distillation tower from which the ammonia vapor is recovered and the lean phosphate solution is separated for reuse. The nature of the Keystone operation is such that additional light oils are recovered from the gas due to the fact that it is cooled and compressed following the conventional light oil scrubbers. The wastewater produced here would presumably be similar to those from the conventional light oil decanter and agitator.

The crude coal tar is usually sold as produced. At some plant, however, the tar is refined using a continuous-type distillation unit with multiple columns and reboilers. Ordinarily continuous distillation results in four fractions: light oils, middle or creosote oils, heavy oils, and anthracene oil which are cuts taken at progressively higher temperatures. The light oils are agitated with sulfuric acid and neutralized with caustic soda after the first crude fractionation and then redistilled. After naphthalene removal, the phenols and other tar acids are extracted from the middle oil fraction with a caustic solution, neutralized and then fractionally distilled. The wastewaters thus contain a variety of organic compounds from process water uses in addition to the cooling and condenser water found from distillation processes.

PRODUCT YIELDS FROM BY-PRODUCT COKE OVENS

Typical products from the carbonization of a ton of coal are as follow:

	SCF
Gas	10,500
Tar	10 gal.
Ammonia	5 lbs.
Tar Acids	2.5 lbs.
Hydrogen Sulfide	5.5 lbs.
Light Oil	3 gals.
Coke	1,380 lbs.
Coke Breeze	150 lbs.

The light oil consists of six fractions separable by boiling point ranges and representing the following percentages by volume of the total light oil:

B.P. Range, °C	Fraction	Percent by Volume
<65	Forerunnings	2.0
65-95	Crude Benzol	60.0
95-127	Crude Tovol	18.0
127-150	Crude Light Solvent	8.0
150-200	Crude Heavy Solvent	6.0
>200	Crude Residue	6.0

Various of the identified components of the light oils are listed below, with percentages by volume of these present in significant concentrations. These compounds are listed roughly in order of increasing boiling points.

n-Pentane	0.2	Benzene	56.5
		n-Hexane	0.1
		2-Methylhexane	
Cyclopentane	0.2	Cyclohexane	0.1
1-Butene	...	2-Hexene	3.0
Butadiene	...	Hexadienes	
Amylenes	0.4	Cyclohexene	
Cyclopentadiene	0.7	1-heptene	
1-hexene	...		
Hydrogen sulfide	...	Thiophene	0.2
Carbonyl sulfide	...	Diethylsulfide	...
Methylmercaptan	...		
Ethylmercaptan	...		
Dimethylsulfied	...		
Carbon disulfide	0.3		
Hydrogen cyanide	...	Methylethylketone	...
		Acetonitrile	...
Acetone	...		

	% by Volume		% by Volume
Toluene	16.5	Ethylbenzene	0.5
n-Heptane		p-Xylene	
n-Octane		m-Xylene	5.2
Methylcyclohexane	0.2	o-Xylene	
Dimethylcyclohexanes			
Unidentified	1.0	n-Nonane	
Methylthiopenes	...	Unidentified	0.3
Pyridine	...	Unidentified	
		Styrene	0.8
		Unidentified	1.0
		Dimethylthiophenes	...
		Methylpridines	...
		Trimethylpyridines	...

			% by Volume
n-Propylbenzene		Naphthalene	1.0
Ethyltoluenes			
Trimethylbenzenes			
Cymenes	3.0		
Tetramethylbenzenes			
n-Decane		Wash oil	4.0
Unidentified		Solvent oils	
		Pitchy residue	1.0
Dicyclopentadiene			
Coumarone			
Indene	3.0		
Methylindene			
Methylcoumarones			
Trimethylthiophene	...		
Thiophenol	...		
Tetramethylthiophene	...		
Dimethylpyridines	...		
Trimethylpyridines	...		
Aniline	...		
o-Toluidine	...		
Phenol	...		
Cresols	...		

The coal tar consists of five fractions separable by boiling point ranges and representing the following percentages of the total tar:

B. P. Range, °C	Fraction	Percent by Weight
< 200	Light Oil	5
200-250	Middle Oil	17
250-300	Heavy Oil	7
300-350	Anthracene Oil	9
> 350	Pitch	62

Compounds are listed below with their relative weight percentages concentrations, roughly in order of increasing boiling points:

	% by Weight	
Crude Tar Bases		2.0
Pyridine	0.1	
Heavy Bases	1.9	
Xylene		1.0
Heavy Solvent Naphtha		1.5
Benzene		0.1
Tolvene		0.2
Tar Acids		2.5
Phenol	0.7	
Higher Tar Acids	0.5	
Xylenols	0.2	
Cresols	1.1	
Naphthalene		10.9
Dimethylnaphthalene		3.4
Methylnaphthalene		2.5
Acenaphthene		1.4
Fluorence		1.6
Anthracene		1.1
Corbazole		1.1
Phenanthrene		4.0
Heavy Oil		21.8
Gas		2.0
Red Was		7.0
Reilly Carbon		32.0
Unidentified		3.9

COKE PLANT PRODUCTION

From published data, as shown in Table I, the daily coke yield per oven is calculated for 11 coke plants. These plants have a total of 3534 by-product coke ovens or 29.1% of the ovens capacity indicated to be available by the American Iron and Steel Institute publication entitled "Directory of Iron and Steel Works of the United States and Canada - 1970". Of the 10,800 operating ovens in 1969, 84% were at least 11 years old as shown below:

Age of Oven in 1969	Number of Ovens	Percent of Total Ovens
20 years or older	3,456	32
11-20 years old	5,616	52
up to 10 years old	1,728	16

In calculating the coke yield of a typical oven, the Burns Harbor and Great Lakes data are withheld as those plants have very large, modern ovens not representative of the typical oven. The average yield for the nine typical plants is 15.31 tons of coke per oven per day, slightly higher than the 14.77 tons of coke per oven per day as calculated by dividing the 1969 coke production by the number of operating ovens in 1969. In calculating the coke production for the plants for which published data was unavailable, the previous two calculated yields were averaged, thus indicating 15.04 tons of coke per oven per day for a typical by-product oven.

TABLE I - COKE PLANT PRODUCTION DATA

Company	Plant	No. of Ovens	Coal Carbonized Tons/day	Coke Produced Tons/day	Yield of coke Per Oven Per day, Tons	Yield of coke From Coal, %
Alan Wood Steel Company	Conshohocken	151	2133	1600	10.60	75.0
Armco Steel Corporation	Houston	62	—	1100	17.74	—
C. F. & I. Steel Corporation	Pueblo	198	4100	2670	13.48	65.1
Bethlehem Steel Corporation	Burns Harbor	82	4750	3000	36.59[2]	63.1
Bethlehem Steel Corporation	Bethlehem	374	—	4800	12.83	—
Jones & Laughlin Steel Corp.	Pittsburgh	315	7380	5366	17.03	72.7
National Steel Corporation	Weirton	294	7100	5287	17.98	74.4
Inland Steel Corporation	Indiana Harbor	523	—	8000	15.30	—
Republic Steel Corporation	South Chicago	75	—	1260	16.80	—
United States Steel Corp	Clairton	1375	31888	22007	16.00	69.0
National Steel Corporation	Great Lakes	85	4807	3317	39.02[1]	69.0
1970 AISI Statistical Abstracts	All	12142	87,208,680	59,776,556	13.49	68.5
1969 AISI - Battelle	All	10800	84,064,635	58,204,506	14.77	69.2

1. Largest ovens on North American Continent, with a height of 20 ft - 2 ins.
2. Next Largest oven on North American continent, with a height of 20 ft - 1 in.

Coke yield for each ton of coal carbonized in the example plants averaged 1,395 pounds or 68.8%. From data on the 10,800 operating ovens in 1969, a yield of 1,384 pounds or 69.24% is indicated. Thus in calculating the coke yield for the typical oven an average was taken of the above calculated yields, and is indicated to be 69.5% or 1,389 pounds of coke per ton of coal carbonized.

From Table I it may be noted that the calculated coke yield and average daily oven production for 1970, assuming all ovens operating is slightly lower than the previous data would indicated. Such data would be invalid as some ovens listed in the A.I.S.I. Directory are not normally operated.

These data indicate the following statistics for the average coke plant:

Number of ovens	238
Coke production:	
Total daily production	3705 tons
Daily production per oven	15.56 tons
Coal coked:	
Total daily use	5328 tons
Daily use per oven	22.38 tons

In Table II, the coke plants owned/operated by the iron and steel industry in 1970 are tabulated. The production statistics are calculated on the basis of the previous data in cases where such statistics are not available directly.

TABLE II - COKE PLANT PRODUCTION CAPACITIES

Plant No.	Company	Plant	State	No. of Ovens	No. of Batteries	By-Product	Bee-Hive	Proposed Additional Ovens	Coal Consumption Tons/day	Coke Produced Tons/day
1.	Alan Wood Steel Company	Conshohocken	Pa.	151	3	✓			2153	1600
2.	Armco Steel Corporation	Hamilton	Ohio	110		✓			2404	1672
3.	Armco Steel Corporation	Houston	Texas	62	2	✓			1582	1100
4.	Armco Steel Corporation	Middletown	Ohio	76		✓			1661	1155
5.	Bethlehem Steel Corporation	Bethlehem	Pa.	374		✓			6902	4800
6.	Bethlehem Steel Corporation	Sparrows Point	MD.	757		✓			16546	11506
7.	Bethlehem Steel Corporation	Lackawanna	N.Y.	494		✓			10798	7509
8.	Bethlehem Steel Corporation	Johnstown	Pa.	316		✓			6907	4803
9.	Bethlehem Steel Corporation	Burns Harbor	Ind.	82	1	✓		82	4750	3000
10.	C F & I Steel Corporation	Pueblo	Colo.	198		✓			4100	2670
11.	Crucible Incorporated	Midland	Pa.	113		✓			2470	1718
12.	Detroit Steel Corporation	Portsmouth	Ohio	70		✓			1530	1064
13.	Donner-Hanna Coke Corporation	Buffalo	N.Y.	151		✓			3300	2295
14	Ford Motor Company	Rouge	Mich	229		✓			5005	3481
15.	Granite City Steel Company	Granite City	Ill.	137		✓			2994	2082
16.	Inland Steel Corporation	Indiana Harbor	Ind.	523		✓			11504	8000
17.	Interlake, Incorporated	Erie	Pa.	58		✓			1268	882
18.	Interlake, Incorporated	Toledo	Ohio	151		✓			3300	2295
19.	Interlake, Incorporated	Chicago	Ill.	100		✓			2186	1520

20.	International Harvester Company	South Chicago	Ill.	112		✓			2448	1702
21.	Jones + Laughlin Steel Corporation	Aliquippa	Pa.	271		✓			5923	4119
22.	Jones + Laughlin Steel Corporation	Pittsburgh	Pa.	315	8	✓			7380	5366
23.	Kaiser Steel Corporation	Fontana	Calif.	316		✓			6885	4788
24.	Lone Star Steel Company	Lone Star	Tex.	78		✓			1705	1186
25.	National Steel Corporation	Great Lakes	Mich.	313		✓			9790	6783
26.	National Steel Corporation	Weirton	W. Va.	294	6	✓		087	7100	5287
27.	Republic Steel Corporation	Youngstown	Ohio	162		✓			3541	2462
28.	Republic Steel Corporation	Warren	Ohio	80		✓			1749	1216
29.	Republic Steel Corporation	Massillon	Ohio	31		✓			678	471
30.	Republic Steel Corporation	Cleveland	Ohio	354		✓			7738	5381
31.	Republic Steel Corporation	South Chicago	Ill.	75		✓			1812	1260
32.	Republic Steel Corporation	Gulfsteel	Ala.	130		✓			2841	1976
33	Republic Steel Corporation	Thomas	Ala.	65		✓			1420	988
34.	Sharon Steel Corporation	Fairmont	W. Va.	60		✓			1311	912
35	Sharon Steel Corporation	Templeton	Pa.	264			✓		5377	3739
36.	Shenango Incorporated	Neville	Pa.	105		✓			2295	1596
37.	United States Pipe + Foundry Company	North Birmingham	Ala.	240		✓			5246	3648
38.	United States Steel Corporation	Clairton	Pa.	1375	22	✓			31888	22007
39.	United States Steel Corporation	Fairfield	Ala.	489		✓			10688	7433
40.	United States Steel Corporation	Fairless	Pa.	174		✓			3803	2645

41	United States Steel Corporation	Gary	Ind	829		✓			18120	12601
42.	United States Steel Corporation	Geneva	Utah	252		✓			5508	3830
43	United States Steel Corporation	Lorain	Ohio	236		✓			5158	3587
44	United States Steel Corporation	Duluth	Minn.	115		✓			2514	1748
45	Wheeling-Pittsburgh Steel Corp.	Steubenville	Ohio	314		✓			6863	4773
46	Wheeling-Pittsburgh Steel Corp.	Monessen	Pa.	93		✓			2033	1414
47.	Woodward Company	Woodward	Ala.	256		✓			5596	3891
48.	Woodward Company	Chattanooga	Tenn.	44		✓			962	669
49	Youngstown Sheet & Tube Company	Campbell	Ohio	228		✓			4984	3466
50	Youngstown Sheet & Tube Company	Brier Hill	Ohio	84		✓			1836	1277
51	Youngstown Sheet & Tube Company	Indiana Harbor	Ind.	237		✓			5180	3602
Total				12142					271,712	188,975

COKE PLANT WASTE WATER DATA

The data of Table III show waste water volumes, sources, and characteristics from some 18 to 35 coke plants. There are some duplications in that data from some particular plants were obtained at different times and/or are included in the two sets of survey data. Counting known variations in operation or data obtained at wide intervals from the same plant as separate samples, 44 samples are included in the data.

In Tables IV, V, VI data are abstracted from Table III to show separately total plant effluents, ammonia liquor, and ammonia still wastes data. In the following sections, these data are used to estimate raw waste loads.

TABLE III - COKE PLANT WASTE WATER DATA

Plant	No. Ovens	Coal tons/day	Coke tons/day	WASTE WATER VOLUME							CONTAMINANTS								Remarks
				Total Plant	Ammonia Liquor	Still Waste	Light Oil Decanter	Final Cooler	Units		Phenol	Cyanide	Ammonia	SCN	Other	UNITS			
									gpd	gal/ton						#/day	#/ton	ppm	
I	62	1583	1190		33,120				x		480	7.2	1457			x			
							108,000		x		2.4	9.6	4.8			x			Includes agitator wastes
								1,440,000	x		125	1872	8743			x			Once-through final cooler
				1581120					x		607	1889	10205			x			
				1581120											265 (1)	x			(1) Sulfur compounds as Sulfi
II	151	2133	1600	180,000					x		2150	55	5000	275	30 (1)			x	(1) Oil and tar
															8500 (2)			x	Indirect NH_3 recovery
															75 (3)			x	(2) Dissolved solids
																			(3) Suspended Solids
III	294	7100	4760			148,000			x		287	265	–		1321 (1)	x			Coking time = 16.73 hours
								73,500	x		820	71	281		1666 (3)	x			Podbielniak extractor -
							(1) 1,625,000		x		514	430	–		634 (3)	x			3500 #/day phenol recovery
							(2) 119,500		x		222	20	23		370 (3)	x			Final cooler tower bleed
				17,203,500					x		1873	795	5804		4302 (3)	x			(1) Absorber Saturator Cond
				17203 500											10906 (4)	x			(2) Benzol Sump
				17203 500											601 (5)	x			(3) BOD
				17203 500											23400 (6)	x			(4) chlorides (5) Oil (6) sulpha
IV	–	3600	–		72,029				x		984					x			
						96,038			x		7.2					x			Vapor Recirculation Dephenoliz
V	376	6902	4800		112,000				x		1300	37.5	4202	934	7003 (1)	x			(1) COD
															9337 (2)	x			(2) Chlorides
VI		2196	1520	13,534,000					x		22.2	114	1079			x			

TABLE III - Continued

Plant	No Ovens	Coal tons/day	Coke tons/day	WASTE WATER VOLUME							CONTAMINANTS								Remarks
				Total Plant	Ammonia Liquor	Still Waste	Light Oil Decanter	Final Cooler	Units		Phenol	Cyanide	Ammonia	SCN	Other	UNITS			
									gpd	gals/ton						#/day	#/ton	ppm	
VII	1375	31888	22007		1,750,000	(1)	460,000		x										(1) Tar Plant
						(2)	160,000		x										(2) Light Oil Plant
						(3)	80,000		x										(3) Claus Carbonate Unit
						(4)	50,000		x										(4) Keystone Light Oil (Cryogen
				2,500,000					x		21000	2000	61000	14600	10500 (5)	x			(5) Sulfides
															21000 (6)	x			(6) Oil and tar
															109000 (7)	x			(7) Dissolved Solids
															69 000 (8)	x			(8) sulfates 24000 + carbonates 34000
															35000 (9)	x			(9) chlorides
VIII	315	7380	5366			259,200			x		2000							x	
								28,800	x		700							x	Final Cooler Tower Bleed
							(1)288,000				4							x	1) Solvent extraction dephenolizer still waste + final cooler bleed
IX	829	18120	12601			429,667			x		1578					x			
						429,667			x		441	52	66	127	8493 (1)			x	(1) total solids
															1103 (2)			x	(2) suspended solids
					[illegible]7,700				x		2290	525	19,873			x			
X	158	3413	2737		75,000						1100		2010	185 (1)	3400 (2)			x	(1) Includes CN as SCN
																			(2) COD
Ohio River Valley						36.8				x	1320		155		4818 (1)			x	No Dephenolizer (1) sulfates + chl
Water Sanitation						31.4				x	158		110		6144 (2)			x	With Dephenolizer (2) sulfates + chlori
Commission -							13.0			x	77		17		88 (3)			x	(3) sulfates + chlorides
17 plant survey						36.8				x	0.404						x		No Dephenolizer
						31.4				x	0.041						x		With Dephenolizer
							13.0			x	0.008						x		

TABLE III -Continued

Plant	WASTE WATER VOLUME							CONTAMINANTS							% volatiles	% moisture	Temperature °F		NH3 Recovery		Dephen.		Remarks
	Total Plant	Ammonia Liquor	Still Waste	Light oil Decanter	Final Cooler	Units		Phenol	Cyanide	Ammonia	SCN	Other	UNITS				Flue	Oven	Semi	Indirect	Vapor	Solvent	
						gal/ton	other						#/ton coal	ppm									
A-1		17				X		300					X		27.8		2300	1760	x				
A-2		18				x		130	7	890			x		30.5	5.7	2470	1930	x				
A-3		19				x		160					x		31.3	6.5	2400	1860	x				
A-1			20			x		46	0.4	7.1		.69 (1) .150 (2)	x				2300	1760	x		x		
A-2			21			x		7.3	4.5	5.7	57		x				2470	1930	x		x		
A-2								11	3.1	9.4			x										Benzol plant wastes
A-2	2960					x		1.9	0.35	2.5				x					x		x		(1) Sulfides (H_2S)
A-2	2960					x		48	8.7	62			x		30.5	5.7	2470	1930	x		x		(2) BOD
A-3								29.															Benzol plant wastes
B		21				x		250	3	490			x		35.4	4.5	2325		x				
B			27			x		48	0.9	28	230	420 (2) 280 (1)	x		35.4	4.5	2325		x		x		
B								56	8.7	12			x				2325		x		x		Benzol plant wastes
B					0			1140	140		140	2690(1)		x			2325		x		x		Closed final cooler
B	4							280	6.0	25	73			x									Wash water to quench
B	4							9	0.2	1	2	32 (1)	x										Wash water to quench
																							(1) BOD
																							(2) Chloride
C		18						80	6	470			x		25.7	4.9	2500		x				
C			23					7.4	2.9	14	66	4 (1)	x		25.7	4.9	2500		x			x	
C								6	1.9				x						x			x	Benzol Plant Wastes
C					0			250	220		290			x			2500						Closed final cooler
C	860							1.9	0.66	1.5	9.3			x									(1) sulfides (H_2S)
C	860							14	5	10	67		x										
D		21						250	6	1080		8 (3) 1800 (2) 470 (1)	x		29.0	1.4	2550		x				
D			33					230	1.0	80			x								0	0	
D								7	1.5	1.2			x										Benzol Plant Wastes
D					0			1700	270		3340			x									Closed final cooler
D	1650							25	0.54	7.4				x									(3) S compounds
D	1250							340	7.5	100		1300 (1)	x										(1) BOD

23

TABLE III - Continued

Plant	WASTE WATER VOLUME							CONTAMINANTS							% Volatiles	% Moisture	Temperature °F		NH3 Recovery		Dephen		Remarks
	Total Plant	Ammonia Liquor	Still Waste	Light Oil Decanter	Final Cooler	Units		Phenol	Cyanide	Ammonia	SCN	Other	Units				Flue	Oven	Semi	Indirect	Vapor	Solvent	
						gal/ton	other						#/1000 tons	ppm									
E-2		28				x		280	26	2400			x		20.0	4.5	2020		x		0	0	
E-1			20			x		72	0.4	870		370(1)	x				2250		x		0	0	
E-3			24			x		120	5.2		240		x				2200		x		0	0	
E-2								0.09	0.02	0.05			x						x		0	0	Benzol Plant Wastes
E-1					1400	x		5	160			495(1)		x			2250						Once-through final cooler
E-2					2420	x		3.8	26			425(1)		x			2020						Once-through final cooler
E-1	1420					x		11	155	78				x			2250						
E-1	1420					x		132	1850	920		6150(1)	x				2250						(1) BOD
E-3					5.8			380	200		730			x			2200						Indirect Condensate
F-2		72						1200	34	5530					25.2	3.0	1740			x	0	0	
F-2	4100							34	0.15	1.5	12			x									
F-2	4100							1170	5	50	420		x										
G			110					640	2	52		.33(3) 1700(2) 1200(1)	x				2460			x	0	0	
G	2740							29	1.7	8.4				x									
G	2740							660	39	90		1320(1)	x										(1) BOD (2) Chloride (3) S compounds
H-2		52						380	120			98(1)			30.9	4.5	2390			x	0	0	
H-1			60					475	2.4	55		1400(1)			30.9		2390			x	0	0	
H-2			68					320	6.3		500				30.9		2390			x	0	0	
H-1								1		5.0				x									Benzol Plant Wastes
H-2								0.5	5.0	14				x									Benzol Plant Wastes
H-1	3450							17	0.14	2.3				x									
H-1	3450							480	4	65		1800(1)	x										(1) BOD
H-2	3670							11	0.20		16			x									(2) S compounds
H-2	3670							330	6		490		x										

TABLE III - COKE PLANT - TOTAL PLANT EFFLUENT

Plant	No. Ovens	Coal tons/day	Coke tons/day	Waste Water Volume		CONTAMINANTS																	Remarks
						Phenol			Cyanide			Ammonia			SCN			B.O.D.		Dissolved Solids		Other		Remarks	
				gpd	gals/ton	#/day	ppm	#/ton	#/day	ppm	#/ton	#/day	ppm	#/ton	#/day	ppm	#/ton	ppm	#/ton	ppm	#/ton	ppm	#/ton		
I	62	1583	1085	1581120	999	607		✓ 0.384	1889		1.194	10205		6.451									0.168	(1) S compounds	Once-through final cooler
II	151	2133	1500	180,000	84.4	3224	2150	✓ 1.511	82.5	55	0.039	7497	5000	3.515	412	275	0.193			8500	(1) 5.975	(1) 30 (2) 75	(1) 0.021 0.053	(1) oil & tar (2) sus. solids	Indirect NH₃ removal
III	394	7100	4760	17,203,500	2423	1873		✓ 0.264	795		0.112	5804		0.817				(1) 4302 (5) 8055	(1) 0.606 (5) 1.135	(5)			1.536(2) 0.025(3) 3.296(4)	(1) 800-#/day (5) 600-#/day	(2) chlorides (3) oil (4) sulphates
VII	1375	31,888	22,007	2,500,000	78.4	21000		✓ 0.659	2000		0.063	61000		1.913	14600		0.458				3.418		(1) 0.659	(1) oil & tar	0.247 #/ton sulfates 1.066 #/ton carbonates 1.098 #/ton chlorides
A-2					2960			0.048			0.007			0.062											
B					4			0.009			0.0002			0.001			0.002		0.032						
C					860			0.014			0.005			0.010			0.067								
D					1650			✓ 0.340			0.008			0.100					1.300						
E-1					1420			0.132			1.850			0.920					6.150						Once-through final cooler
F					4100			✓ 1.170			0.005			0.050			1.420								
G					2740			✓ 0.660			0.039			0.090					1.320						
H					3560			✓ 0.405			0.005			0.065			0.490		1.800						
Interlake	100	2186		13536000	6192	22.2		0.010	114		0.052	1079		0.494											

25

TABLE I - COKE PLANT - AMMONIA LIQUOR

Plant	No. Ovens	Coal tons/day	Coke tons/day	Waste Water Volume		Contaminants																			Remarks
						Phenol			Cyanide			Ammonia			SCN			B.O.D.		Dissolved Solids		Other		Remarks	
				gpd	gals/ton	#/day	ppm	#/ton	#/day	ppm	#/ton	#/day	ppm	#/ton	#/day	ppm	#/ton	ppm	#/ton	ppm	#/ton	ppm	#/ton		
I	62	1,582	1,085	33,120	20.9	460		0.303	7.2		0.005	1457		0.921											
IV		3,600		72,029	20.0	984		0.273																	
V	376	6,902	4,800	112,000	16.2	1300		0.188	37.5		0.005	4202		0.609	934		0.135		(1) 1.015				(2) 1.353	(2) chlorides (1) C.O.D.	
VII	1375	31,888	22,007	1,750,000	54.9																				
IX	829	18120	12,601	397,700	21.9	2270		0.126	525		0.029	19873		1.097											
X	158	3,413	2,737	75,000	22.0	.687	1100	0.201				1256	2010	0.368	(1) 116	(1) 185	(1) 0.034	(2) 3400	(2) 0.622					(2) COD (1) includes CN	
A-1					17			0.300																	
A-2					18.			0.130			0.007			0.870											
A-3					17			0.150																	
B					21			0.250			0.008			0.490											
C					18			0.080			0.006			0.470											
D					21			0.750			0.066			1.090											
E-2					28			0.280			0.026			2.400											
F-2					72.			1.200			0.054			5.590											
H-2					52.			0.380			1.120														

2652

TABLE VI - COKE PLANT - AMMONIA STILL WASTES

Plant	No. Ovens	Coal tons/day	Coke tons/day	Waste Water Volume		Contaminants																		Remarks	Remarks
						Phenol			Cyanide			Ammonia			SCN			B.O.D.		Dissolved Solids		Other			
				gpd	gals/ton	#/day	ppm	#/ton	#/day	ppm	#/ton	#/day	ppm	#/ton	#/day	ppm	#/ton	ppm	#/ton	ppm	#/ton	ppm	#/ton		
III	294	7100	4760	148,000	20.8	287		0.040	265		0.037							(1) 1321	0.186					(1) #/day	Dephenolizer Free NH3 still only
IV		3600		96,038	26.7	7.2		0.002																	Dephenolizer
VIII	315	7380	5366	259,200	35.1	4318	2000	0.585	✓																No Dephenolizer
VIII	315	7380	5366	259,200	35.1	8.64	4	0.001																	Dephenolizer
IX	829	18120	12601	429,667	23.7	1578	441	0.087	186	52	0.0103	236	66	0.013	455	127	0.025			7390	1.459	(1) 1103	0.218	(1) S.S.	
					36.8		1320	0.404	✓				155	0.048						4818	1.476	4350 (1) 468 (2)	1.393 (1) 0.143 (2)		(1) Cl (2) SO4 No Dephenolizer
					31.4		158	0.041					110	0.029						6144	1.607	5400 (1) 744 (2)	1.412 (1) 0.195 (2)		(1) Cl (2) SO4 With Dephenolizer
A-1					20			0.046			0.0304			0.0071									0.669 (1) 0.350 (2)	Semi-direct Dephenolizer	Flue Temp. 2300 °F
A-2					21			0.007			0.0045			0.0057			0.057							(1) S (2) 800	Flue Temp. 2470 °F
B					27			0.048			0.0009			0.028			0.230						.423 (1) .280 (2)	Semi-direct Dephenolizer	(1) chloride (2) 800 Flue Temp. 2325 °F
C					23			0.0074			0.0029			0.014			0.066						.004 (1)	Semi-direct Dephenolizer	(1) S Flue Temp. 2305 °F
D					33			0.230	✓		0.001			0.080									0.002 (1) 1.850 (2) 0.420 (3)	Semi-direct No Dephenolizer	(1) 800 (2) chloride (3) Flue Temp. 2350 °F
E-1					20			0.072	✓		0.0004			0.870									.370 (1)	Semi-direct	(1) 800 Flue Temp. 2350 °F
E-2					24			0.120	✓		0.0052						0.240							no dephenolizer	Flue Temp. 2200 °F
G.					110			0.640			0.002			0.052									0.033 (1) 1.800 (2) 1.700 (3)	no dephenolizer indirect	(1) 800 (2) chloride (3) Flue Temp. 2460 °F
H-1					60			0.475			0.0024			0.033									0.031 (1) 1.400 (2)	no dephenolizer indirect	(1) 800 (2) S Flue Temp. 2390 °F
H-2					68			0.320			0.0063						0.500								Flue Temp. 23[illegible]

TOTAL EFFLUENT RAW WASTE LOADS

Raw waste loads for coke plant effluents are highly variable due to the nature of the production processes, the nature of the waste treatment/disposal means, the nature of the water use systems, and the extent to which process and cooling waters are combined. The latter, in particular, defines the waste water volume when uncontaminated cooling water is not considered.

The standard raw waste volume for all coke plant effluents is best estimated at 2,862 gals. per ton of coal coked on the basis of the U.S.G.S. 15-plant survey which was specifically directed toward attaining this statistic. Specific total plant effluent data from 6 coke plants ranging from small to large and ranging from once-through to closed-loop cooling systems average 2,680 gals. per ton of coal. The minimum and maximum volumes from specifically known plants are 461 and 6,192 gals. per ton of coal, respectively. The former discharges cooling tower blowdown, ammonia still wastes and some benzol plants wastes. The latter uses water once-through.

Insofar as the effluent phenol load is concerned, consideration must be taken of the ammonia removal system, the nature of the final cooler system, and whether or not treatment has been employed. Of the plant data available, several plants use indirect ammonia recovery and once-through final coolers; they are not typical practice. Grouping the phenol loads by in-plant processes:

Coke Plant Effluents (Gals. per ton Coke)

Measure	Cooling Water Once-Through	Recirculated	Process Water	Total
Minimum	899	0	0	69
Maximum	9220	622	1590	9390
Median	4130	84	364	3890
Average	4070	182	501	4120

U.S.G.S. Water-Supply Paper 1330-H (15 plant survey)

Coke Plant Effluents (Gals. per ton Coal)

(Basis: 69.47% yield)

Measure	Cooling Water Once-Through	Recirculated	Process Water	Total
Minimum	625	0	0	48
Maximum	6405	432	1105	6523
Median	2869	58	253	2702
Average	2827	126	348	2862

Coke Plant Effluent Data

	Coal, tons/day	Plant Flow. gpd	gals./ton coal
VI	2,186	13,536,000	6192
XI	5,180	21,550,000	4160
XII	10,688	17,300,000	1619
XIII	2,448	1,127,520	.461
III	7,100	17,203,500	2423
IX	18,120	22,200,480	1225
			2680

		Phenol,# / ton coal
	Indirect ammonia recovery:	
II , F	No ammonia still	1.341
G, H	Ammonia still, no dephenolizer	0.533
	No ammonia recovery:	
VII	Except after benzol plant	0.659
I	Once-through final cooler	0.384
	Semi-direct ammonia recovery:	
	Ammonia still, no dephenolizer:	
D	Closed final cooler	0.340
E	Once-through final cooler	0.132
	Ammonia still with dephenolizer:	
III	Podbielniak extrator	0.264
C	Benzol extraction	0.014
A-2, B	Vapor Recirculation	0.029
VI	Unknown	0.010

The range of phenol loads is 0.010 to 1.511 lbs. per ton of coal. Those plants with ammonia stills increasingly do not operate them; many plants do not operate dephenolizers even if they have done so in the past. Once-through final coolers are rare. The most likely raw waste load factor for phenol is probably best estimated on the basis of current practice as a weighted average based on numbers of ovens of the VII and III plants representing 85% of production prolice, with indirect ammonia recovery using stills as the remainder:

$$\begin{array}{r}0.659 \times 1375 = 906.13\\ 0.264 \times 294 = \underline{77.62}\\ 983.75 \div 1669 = 0.589\end{array}\ \text{lbs. phenol/ton coal}$$

$(0.589 \times 0.85) + (0.533 \times 0.15) = 0.581$ lbs. phenol/ton coal

The predominant factor in effluent cyanide loads is the operation of the final cooler, i.e., the extent to which the system is closed.

	Final Cooler Effluent, gals/ton coal	Effluent CN, lbs./ton coal
E-1	1400 (Once-through)	1.850
I	910 (Once-through)	1.194
III	10.4 (Once-through)	0.112
	Unknown final cooler effluent volume:	
VII	No ammonia recovery except after benzol plant	0.063
II , F,G,H	Indirect ammonia recovery	0.022
A-2	Semi-direct NH recovery, still, dephenolizer	0.009
VI	Unknown processes	0.052
C,B,D	Zero final cooler effluent	0.0044

The range of cyanide loads is 0.0002 to 1.850 lbs. per ton of coal as shown in Table IV. The most likely raw waste load factor for cyanide is probably again best estimated on a weighted basis as for phenol:

$$\begin{array}{l} 0.063 \times 1375 = 86.63 \\ 0.112 \times 294 \;\; = \underline{32.93} \\ \qquad\qquad\quad 119.56 \div 1669 = 0.0716 \text{ lbs. CN/ton coal} \end{array}$$

$$(0.0716 \times 0.85) + (0.022 \times 0.15) = 0.064 \text{ lbs. CN/ton coal}$$

Effluent ammonia loads depend primarily on the extent of ammonia recovery. Ammonia in the gas ranges from 4 to 7 lbs. per ton of coal, thus setting an upper effluent load limit for no recovery. Ammonium sulfate production has been discontinued by many plants. Even when ammonia stills are operated, the fixed legs are frequently not operated. Once-through final cooler water washes much of the remaining ammonia from the gas.

		NH_3 lbs./ton coal
I	No ammonia recovery, once-through final cooler	6.451
II	Indirect ammonia recovery, no ammonia stills	3.515
VII	No NH_3 recovery (except after benzol plant)	1.913
E-1	Semi-direct NH_3 recovery, NH_3 still, once-through final cooler	0.920
III	Semi-direct NH_3 recovery, free NH_3 still only	0.817
VI	Unknown	0.494
A-2, B, C, D	NH_3 recovery, NH_3 stills (semi-direct & indirect)	0.043
F,G,H	NH_3 recovery, NH_3 still, indirect	0.068

The most likely basis for estimating the raw waste load factor for ammonia is on the weighted average of Clairton and Weirton, since most plants either do not operate the ammonia stills as at Clairton or operate only the free still as at Weirton:

$$\begin{array}{l} 1.913 \times 1375 = 2630 \\ 0.817 \times 294 = \underline{240} \\ \overline{2870} \div 1669 = 1.720\ {}^{\#}NH_3/\text{ton coal} \end{array}$$

Effluent data on thiocyanates are scant. The available data, however, rather clearly show the major deterants of effluent loads:

	SCN/# ton coal
No ammonia recovery (except after benzol plant)	0.458
Indirect ammonia recovery	0.368
Semi-direct ammonia recovery	0.035

The raw waste load factor is probably best estimated on the basis of the average of the 6 plants for which data are directly available, since they represent a fair sample of current practice, i.e., 0.272 lbs. SCN/ ton coal. This is essentially the same value as would be obtained from the above data taking the value for indirect ammonia recovery at 15% of the total with the average of the other 2 values representing 85% of the total.

Values of B.O.D. in total plant effluents are likewise scant, but seem to group as follow on the basis of production processes:

	#BOD/ton Coal
Once-through final cooler	6.150
Ammonia recovery, no dephenolizer	1.473
Ammonia recovery, free still only	0.606
Ammonia recovery, ammonia still, dephenolizer	0.032

The average of the above data, throwing out the case of the once-through final cooler, i.e., 0.704 lbs. per ton of coal probably best estimates current practice.

Dissolved solids and oil and tar are probably best estimated on the basis of the weighted averages of the Clairton data as representing 85% of production and the Alan Wood data as representing 15% of production:

Dissolved Solids: (3.418 x 0.85) + (5.975 x 0.15) = 3.802 #/ton coal

Oil and Tar: (0.659 x 0.85) + (0.021 x 0.15) = 0.563 #/ton coal

Suspended solids are indicated to range from 30 to 120ppm in the Alan Wood effluent. This would probably represent a fair estimate of suspended solids other than in still wastes, i.e., 0.053 #/ton coal. C.O.D. is available only as a final effluent parameter in the case of Weirton where a load of 1.135 #/ton coal is indicated.

Sulphates and chlorides are probably best estimated as the weighted average of the Weirton and Clairton data:

Chlorides:

$$\begin{array}{rl} 1.536 \times 294 = & 451.6 \\ 1.098 \times 1375 = & \underline{1509.8} \\ & 1961.4 \div 1669 = 1.175\ ^{\#}\text{Cl/ton coal} \end{array}$$

Sulphates:

$$\begin{array}{rl} 3.296 \times 294 = & 969.0 \\ 0.847 \times 1375 = & \underline{1164.6} \\ & 2133.6 \div 1669 = 1.278\ ^{\#}SO_4/\text{ ton coal} \end{array}$$

The only effluent sulfide data available is for Armco, i.e., 0.168 $^{\#}$S/ ton coal.

AMMONIA LIQUOR RAW WASTE LOADS

The volume of ammonia liquor depends primarily upon whether the semi-direct or indirect ammonia recovery process is used, and also upon the moisture and volatility of the coal and the carbonizing temperature. The volume of ammonia liquor at the minimum is the amount of moisture volatilized from the coal. The actual volume of effluent depends upon to what extent additional water is added. All of the available data include 2 out of 13 indirect ammonia recovery examples, i.e. 15 percent. The average of all thus represents a fair sample of the industry, including the obviously high example of VII. The volume range may thus be taken as from 16.2 to 72 gals. per ton of coal with an average of 29.7.

Phenol varies in the ammonia liquor primarily due to the nature of the ammonia recovery process, the carbonization temperature, and the volatility of the coal. The relative effects can be estimated from the examples plants as follows:

Plant	Flue Temp., ^{0}F	Oven Temp., ^{0}F	Coal Volitility, ^{0}F	Phenol, #/ton coal
A-1	2300	1760	29.8	0.300
A-2	2470	1930	30.5	0.130
A-3	2400	1860	31.3	0.160
H-2	2390	--	30.9	0.320

The phenol load in the ammonia liquor from indirect ammonia recovery is about twice that from semi-direct ammonia recovery as shown in comparing H-2 and A-3. The variation with carbonization temperature is shown in comparing A-1, A-2, and A-3. The volume of water used is the primary determinant of variations between indirect ammonia recovery systems.

The phenol load variation is from 0.080 to 1.20 lbs. of phenol per ton of coal. The indicated ammonia recovery variations are as follows:

Semi-direct ammonia recovery	0.215 #phenol/ton coal
Indirect ammonia recovery:	
52 gals. liquor/ton coal	0.380 #phenol/ton coal
72 gals. liquor/ton coal	1.200 #phenol/ton coal

The standard raw waste load might be estimated from a weighted average of the above data: $(0.215 \times 0.85)+\left(\frac{1.200 + 0.380}{2}\right) 0.15 =$

0.302 #phenol/ton coal

considering, however, that the data on still wastes is more extensive and that a phenol reduction of 88.1% (D and H-2) is indicated with ammonia stills, the waste load factor is probably best estimated from the ammonia still data as $\frac{0.409}{0.881} =$

0.464 #phenol/ton coal.

The cyanide load in the ammonia liquor varies from 0.003 to 0.120 lbs. per ton of coal as shown in Table V. Cyanide is generally higher in the liquor from indirect ammonia recovery systems; comparing plant F-2 and IX, however, show that this generality probably cannot be quantified. The most likely raw waste load factor is the average of the sample, i.e., 0.024 lbs. CN/ton coal. Ammonia is likewise estimated as the average of the sample, i.e., 1.386 lbs. NH_3/ton coal.

Taking the volume for semidirect ammonia recovery at 25 gals. per ton of coal and for indirect ammonia recovery at 62 gals/ton, from the above data:

	Semi-direct #/ton coal	Indirect #/ton coal
Total NH_3 =	1.438	2.129
Free NH_3 =	0.934	1.568
Fixed NH_3 =	0.504	0.561
Sulfide =	0.118	0.581
Thiosulfate =	0.054	
Sulfite =	0.577	
Sulfate =	0.031	
Chloride =	0.872	
Cyanide =	0.011	
Thiocyanite =	0.080	
Ferrocyanide =	0.005	
Total Sulfur =	0.165	
Phenol =	0.389	
Pyridine =	0.067	0.581

These data for ammonia, phenols, cyanide, and thiocyanate compare favorably with the previous sample data for specific plants. The other parameters may thus be added as above with reasonable confidence. Sulfide and pyridine are estimated on the basis of a weighted average according to ammonia recovery practice, i.e., 85% semi-direct and 15% indirect. Ferrocyanide and thiosulfate were estimated per the available data.

Load factors for other components can only be estimated as averages of the available data:

Thiocyanates	0.085 #/ton coal
C.O.D.	0.819 #/ton coat
Chlorides	1.353 #/ton coal

B.O.D. may be estimated at 0.410 #/ton coal on the basis of the B.O.D./C.O.D. correlation given in a following section.

Additional data taken from Wilson and Wells can be used to both verify raw Ammonia Liquor load data and to add other parameters. The data are presented in the reference as follows:

Compositions of Weak Ammonia Liquors From Several Coke Plants

	Ammonia-recovery process			
	Semidirect		Indirect	
Plant	A	B	C	D
Ammonia, total, gpl	7.60	6.20	4.65	3.59
Free, gpl	4.20	4.76	3.37	2.70
Fixed, gpl	3.40	1.44	1.28	0.89
Carbon dioxide as CO_2, gpl	2.35	3.94	2.78	1.74
Hydrogen sulfide as H_2S, gpl	0.86	0.34	1.26	1.13
Thiosulfate as $H_2S_2O_3$, gpl	0.022	0.51		
Sulfite as H_2SO_3, gpl	2.84			
Sulfate as H_2SO_4, gpl		0.15		
Chloride as HCl, gpl	6.75	1.85		
Cyanide as HCN, gpl	0.062	0.05		
Thiocyanate as HCNS, gpl	0.36	0.42		
Ferrocyanide as $(NH_4)_2Fe(CN)_6$, gpl	0.014	0.039		
Total sulfur, gpl	1.014	0.57		
Phenols as C_6H_5OH, gpl	0.66	3.07		

Compositions of Weak Ammonia Liquors From Several Coke Plants (cont.)

	Ammonia-recovery process			
	Semidirect		Indirect	
	A	B	C	D
Pyridine bases as C_5H_5N, gpl	0.48	0.16	1.27	0.98
Organic number, cc N/50 $KMnO_4$ per liter			4856	3368

A standard factor for the percentage of fixed ammonia can be estimated from the above on the basis of a weighted average between semi-direct and indirect ammonia recovery:

$$\frac{0.85(0.504) + 0.15(0.561)}{0.85(1.438) + 0.15(2.129)} \times 100 = 33\%$$

AMMONIA STILL RAW WASTE LOADS

The volume of still wastes are primarily determined by the volume of ammonia liquor preduced, i.e., upon the volume of input to the still. Comparisons are as follows:

	Volume, gals./ton coal		
Plant	Ammonia Liquor	Still Waste	Ratio
IV	20.0	26.7	1.335
IX	21.9	23.7	1.082
A-1	17	20	1.176
A-2	18	21	1.667
B	21	27	1.286
C	18	23	1.278
D	21	33	1.571
H-2	52	68	1.308

The observed range of still wastes volume is from 20 to 110 gals. per ton, the higher volumes resulting from indirect ammonia recovery ststems. The average ratio above includes a 33.8% increase in still waste volume over that of the ammonia liquor. The sample plants total 28 with only 2 being indirect ammonia recovery systems. The volume for semi-direct systems average 31.2 gals. per ton of coal; for the indirect systems the average is 87.0 gals per ton of coal. A weighted average of the raw waste load volume are:

(0.85 x 31.2) + (0.15 x 87.0) = 39.57 gals/ton coal

1.338 x 29.7 = 39.74 gals/ton coal

An average value of 39.7 gals. per ton of coal is indicated.

The primary determinants of phenol in the still waste are, of course, the phenol in the ammonia liquor and the use and nature of dephenolizers. From the available data:

	#phenol/ton coal
Indirect Ammonia Recovery:	
No Dephenolizers	0.519
Semi-Direct Ammonia Recovery:	
No Dephenolizers	0.389
Unknown	0.087
Dephenolizers:	
Vapor recirculation and benzol extraction	0.041
Podbielniak extractor	0.040
Vapor recirculation	0.026
Benzol extraction	0.004

The range of phenol loads with no dephenolizers is from 0.096 to 0.640 lbs. phenol/ton coal. The weighted average is estimated as:

(0.85 x 0.389) + (0.15 x 0.519) = 0.409 #phenol/ton coal

The range of phenol loads with dephenolizers is from 0.001 to 0.048 lbs. phenol/ton of coal. The average of the data for semi-direct ammonia recovery is 0.036 lbs. phenol/ton coal, indicating a phenol removal efficiency of 90.7%, about equal to that indicated by the ORSANCO data. The standard waste load, applying this removal efficiency, would be 0.038 lbs. phenol/ton coal.

The range of cyanide loads is from 0.004 to 0.037 lbs. per ton of coal. The highest value was from a plant operating only the free leg of the ammonia still. There is no consistently apparent variation in cyanide loads between indirect and semi-direct ammonia recovery systems, with or without dephenolizers. The average of the sample data is probably the best standard load factor, i.e., 0.007 #/ton coal.

The ammonia in the still waste depends upon whether or not the free and fixed stills are operated, whether or not a dephenolizer is operated, and upon the efficiency of the still. The ammonia is present in ammonia liquor in approximately equal amounts as free and fixed ammonia. The range of observed values is 0.006 to 0.870 lbs. ammonia per ton of coal. There is no demonstratable difference between the semi-direct and indirect ammonia recovery processes with ammonia stills.

	#NH_3/ton coal
Free and Fixed Ammonia Stills:	
No dephenolizers	0.089
Dephenolizers	0.027
Unknown	0.013

Taking the removal of free ammonia at 67% of the total in the ammonia liquor with the operation of the free still only, the standard load factor would be 0.693 #NH_3/ton coal.

The thiocyanate load varies from 0.025 to 0.500 lbs. per ton of coal. The highest value is in a case of indirect ammonia recovery, but there is no clearcut variation with and without dephenolizers. The standard load factor is probably best estimated as equal to that of the ammonia liquor, i.e., 0.085 #/ton coal.

The other factors are best estimated as the averages of the available data:

	Load Factors
No Dephenolizers	1.476 #d.s./ton coal
With Dephenolizers	1.607 #d.s./ton coal
Suspended Solids	0.218 #s.s./ton coal

	Load Factors	
	With Dephenolizer	No Dephenolizer
Sulfides:	0.037	0.024
B.O.D.:	0.215	0.552 (2)
Chlorides:	1.357	1.377
Sulfates:	0.195	0.143

(1) Averaged as 85% semi-direct and 15% indirect ammonia recovery.

FINAL COOLER RAW WASTE LOADS

Final cooler water volumes from the available data are as follows:

	System	Vol. gal./ton coal
I	Once-through	910
E-1	Once-through	1400
E-2	Once-through	2420
E-3	Cooling coil condensate	5.8
III	Cooling tower bleed	10.35
VIII	Cooling tower bleed	3.90

The standard factors may thus be taken as 1410 gals. per ton of coal for once-through systems and 6.68 gals. per ton for recirculating systems. Since once-through systems are practically non-existent, the latter is the most likely factor.

Contaminant loads from the sample data are as follows:

		Load, #/ton coal				
	System	Phenol	Cyanide	Ammonia	B.O.D.	SCN
I	Once-through	0.079	1.183	5.527		
E-1	Once-through	0.058	1.866		5.773	
E-2	Once-through	0.077	0.524		8.568	
III	Cooling Tower Bleed	0.115	0.010	0.040	0.235	
VIII	Cooling Tower Bleed	0.095				
E-3	Cooling Loil Condensate	0.018	0.010			0.035
		Concentrations, ppm				
C	closed	250	220			290
D	closed	1700	270			3340
B	closed	1140	140		2890	140

The average loads then for once-through and recirculating systems may be estimated as follows:

Load Factors

System	Phenol	Cyanide	Ammonia	SCN	B.O.D.
Once-through	0.073	1.189	5.527	4.162 (1)	7.171
Recirculating	0.076	0.010	0.040	0.035	0.235

(1) assumed on basis of same ratio as for cyanide between 2 systems.

The average concentrations for the closed systems and the estimated waste water effluent volume for recirculating systems yields the following average waste loads:

Phenol	0.057 #/ton coal
Cyanide	0.012 #/ton coal
Thiocyanate	0.070 #/ton coal
B.O.D.	0.160 #/ton coal

Considering the range of data, these values may be taken as in good agreement.

BENZOL PLANT RAW WASTE LOADS

Benzol plant waste waters measured at 8 plants by Black,et.al., showed 375 to 750 gals. per ton of coal for systems including cooling water and 20 to 89 gals. per ton of coal for systems where cooling water was recycled or discharged seperately. Light oil decanter wastes in the ORSANCO data averaged 13 gals. per ton of coal. The III example indicates 246 gals. per ton of coal for the principal contamined waste waters. The Clairton data indicate 14.4 gals. per ton of coal for a tar plant. The most likely waste load factor for the benzol plant waste volume is the minimum volume including cooling water, i.e., 375 gals/ ton coal.

The sample data indicate the following waste loads:

	Load, #/ton coal				
Plant	Phenol	Cyanide	Ammonia	SCN	B.O.D.
III	0.104	0.063			0.141
A-2, A-3	0.020	0.003	0.009		
B	0.056	0.009	0.012		
C	0.006	0.002			
D	0.007	0.002			
E-2	0.0009	0.0002	0.0005		
H-1, H-2	0.0008	0.005	0.0095		

The most likely raw waste load factors are the averages of the available data:

Phenol	0.028#/ton coal
Cyanide	0.012#/ton coal
Ammonia	0.008#/ton coal
B.O.D.	0.141#/ton coal

The ORSANCO data are the best available specifically for light oil decanter wastes:

	Load Factors
Phenol	0.008 #/ton coal
Ammonia	0.0018 #/ton coal
Chloride	0.0053 #/ton coal
Sulphate	0.0038 #/ton coal

RAW WASTE LOADS-SUMMARY DATA

The estimated raw waste load data are summarized in Table VII.

In Figure 2, the variations in phenol production in ammonia liquor are shown as functions of carbonizing temperatures.

In Figure 3, the relationship between B.O.D. and C.O.D. determined in a variety of coke plant waste waters is shown (Weirton data).

LOCATIONS OF COKE PLANTS

The distributions of coke ovens by state in 1970 is shown in Figure 4.

TABLE VII - RAW WASTE LOADS-SUMMARY DATA

Parameter (per ton coal)	Total Effluent	Ammonia Liquor	Ammonia Still Wastes			Final Cooler	Benzol Plant	Light Oil Decanter
			Free&Fixed	Free Still only	Dephenolizers			
Vol., gal.	2862	29.7	39.7			6.88	375	13
Phenol, lb.	0.581	0.464	0.409		0.038	0.076	0.028	0.008
Cyanide, lb.	0.064	0.024	0.007			0.010	0.012	
Ammonia, lb.	1.602	1.386	0.089	0.457	0.027	0.040	0.008	0.0018
Thiocyanate, lb.	0.265	0.085	0.085			0.035		
B.O.D., lb.	1.473	0.410	0.552		0.215	0.235	0.141	
Dissolved Solids, lb.	3.802		1.476		1.607			
Oil and Tar, lb.	0.563							
Chlorides, lb.	1.175	1.353	1.377		1.357			0.0053
C.O.D., lb.	2.946	0.819						
Suspended Solids, lb.	0.053		0.218					
Sulphate, lb.	1.278		0.143		0.195			0.0038
Sulfides, lb.	0.168	0.187	0.024		0.037			
Ferrocyanide, lb.		0.005						
Pyridine, lb.		0.144						
Thiosulfate, lb.		0.054						

Figure 2- Phenol in Ammonia Liquor as a Function of Coking Temperatures

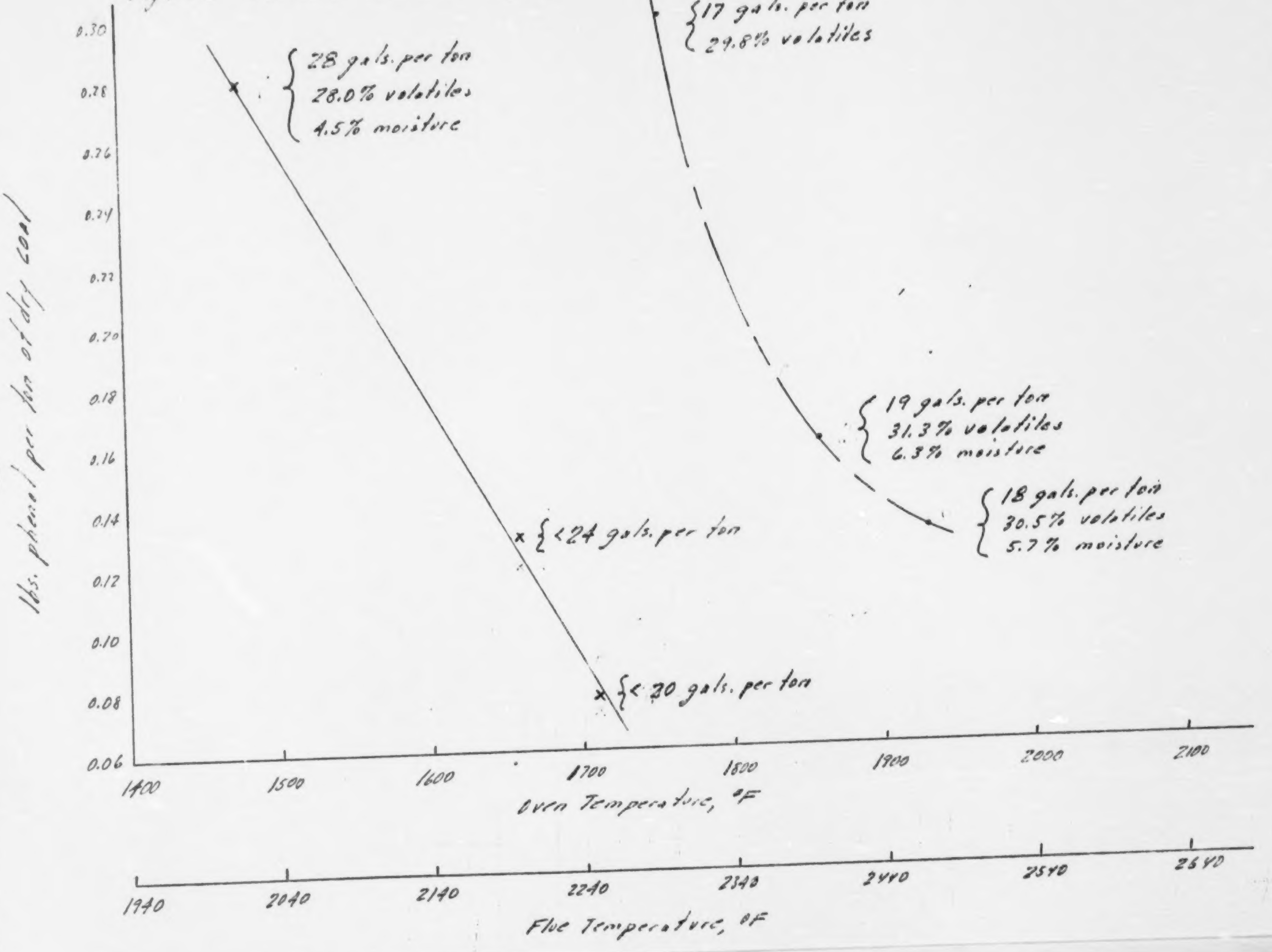


Figure 3- BOD vs. COD for Various Coke Plant Waste Waters

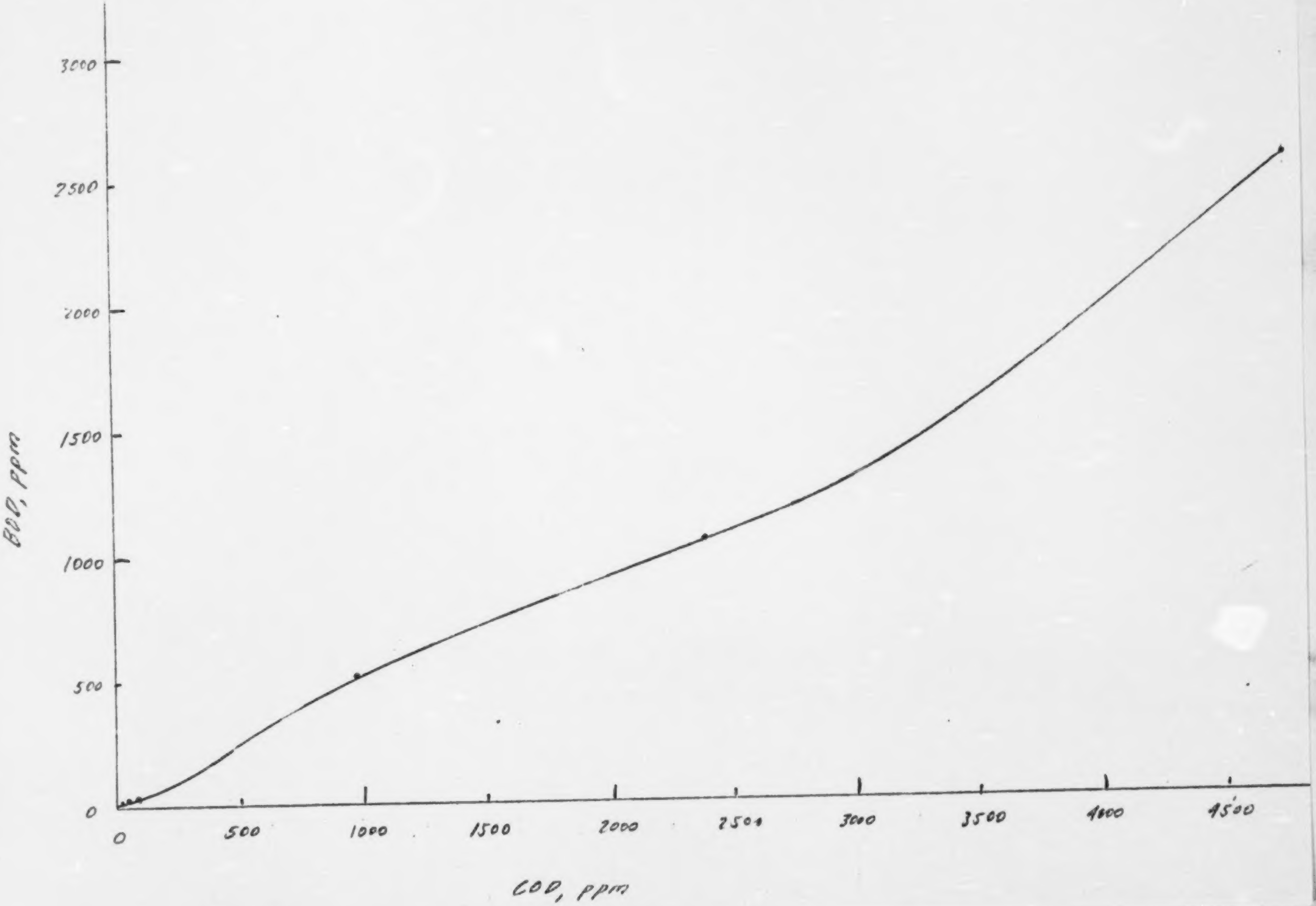
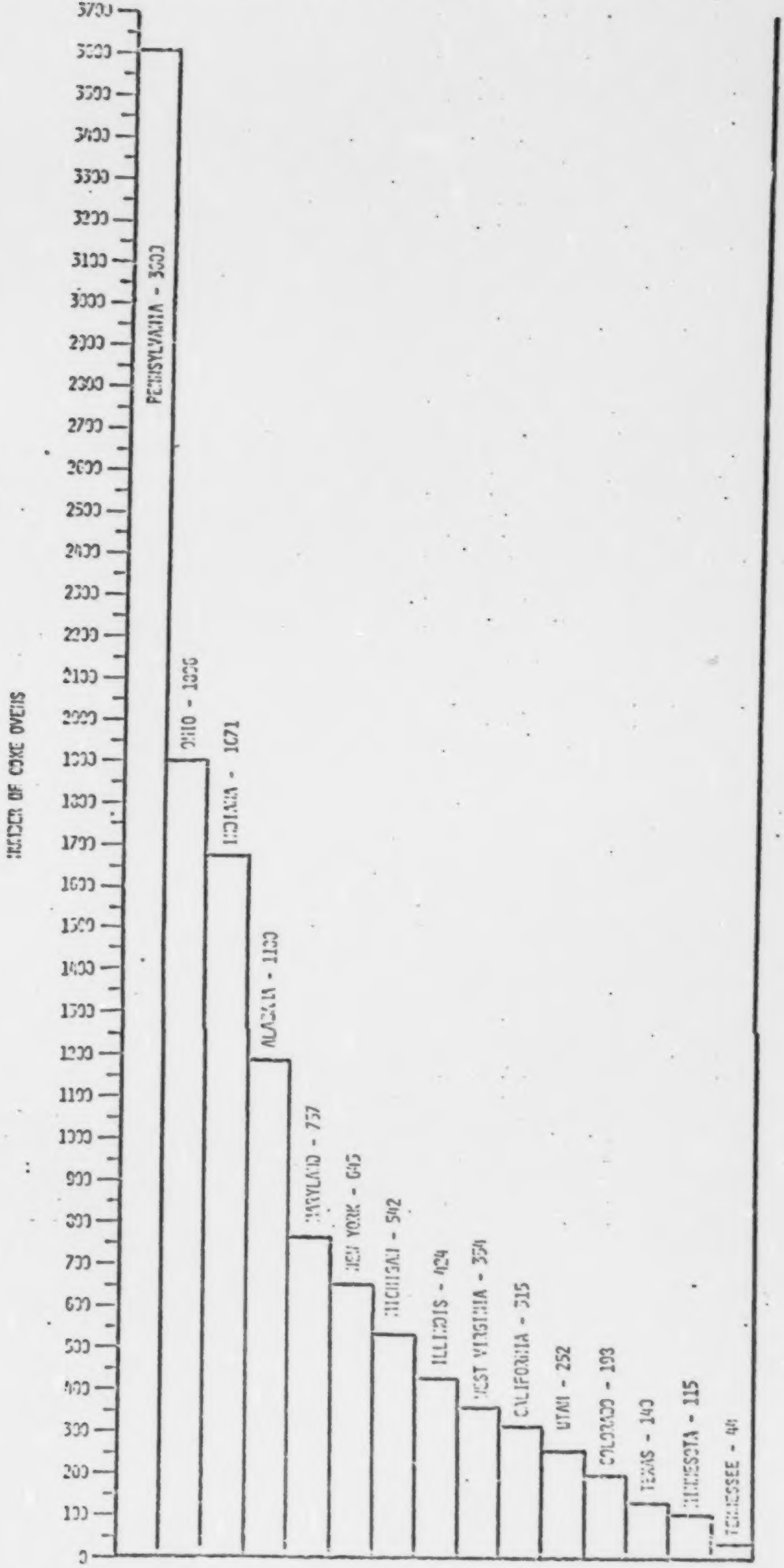


FIGURE 4
DISTRIBUTION OF COKE OVENS BY STATE



The Standard Raw Waste Load of the "average" coke plant may be estimated on the basis of the following operating conditions:

1. Direct discharge of flushing liquor
2. No ammonia stills or saturators
3. Once-thru final cooler
4. Benzol plant

Parameter	Flushing Liquor	Final Cooler	Benzol Plant	Total Effluent
Flow, gal/ton	29.7	1410	375	4255
Phenol, #/ton	0.464	0.073	0.028	0.565
Cyanide, #/ton	0.024	1.189	0.012	1.225
Ammonia, #/ton	1.386	5.527	0.008	6.921
Thiocyanate, #/ton	0.085	4.162	-	> 4.247
B.O.D., #/ton	0.410	7.171	0.141	7.722
Chlorides, #/ton	1.353	-	-	> 1.353
C.O.D., #/ton	0.819	-	-	> 15.4
Sulfide, #/ton	0.187	-	-	> 0.187
Ferrocyanide, #/ton	0.005	-	-	0.005
Pyridine, #/ton	0.144	-	-	0.144
Thiosulfate, #/ton	0.054	-	-	> 0.054

Present Practice Waste Loads in the "average" coke plant may be estimated on the basis of operating practices approximately as follow:

1. Direct discharge of flushing liquor - 70% of plants
   Semi-direct ammonia recovery - 15% of plants
   Indirect ammonia recovery - 15% of plants
2. Recirculating final cooler with cooling tower bleed.
3. Benzol plant

Parameter	Final Cooler	Benzol Plant	Total Effluent
Flow, gal./ton	6.9	375	2862
Phenol, #/ton	0.076	0.028	0.581
Cyanide, #/ton	0.010	0.012	0.064
Ammonia, #/ton	0.040	0.008	1.602
Thiocyanate, #/ton	0.035	-	0.265
B.O.D., #/ton	0.235	0.141	1.473
Dissolved Solids, #/ton	-	-	3.802
Oil and Tar, #/ton	-	-	0.563
Chlorides, #/ton	-	-	1.175
C.O.D., #/ton	-	-	2.946
Suspended Solids, #/ton	-	-	0.053
Sulphates, #/ton	-	-	1.278
Sulfides, #/ton	-	-	0.168

The Base Level of Treatment can most logically be specified as the treatment that has been demonstrated and utilized for 20 years, i.e., the use of free and fixed ammonia stills, dephenolizers, and recirculated final coolers with cooling tower bleed. The BLT loads are thus estimated as follows, assuming the use of a benzol extraction dephenolizer.

Parameter	Still Waste	Final Cooler	Benzol Plant	Total Effluent
Flow, gal./ton	39.7	6.9	375	2862
Phenol, #/ton	0.004	0.076	0.028	0.108
Cyanide, #/ton	0.007	0.010	0.012	0.029
Ammonia, #/ton	0.027	0.040	0.008	0.075
Thiocyanate, #/ton	0.085	0.035	-	>0.120
B.O.D., #/ton	0.215	0.235	0.141	0.591
Dissolved Solids, #/ton	1.607	-	-	>1.607
Chlorides, #/ton	1.357	-	-	>1.357
Suspended Solids, #/ton	0.218	-	-	>0.218
Sulphates, #/ton	0.195	-	-	>0.195
Sulfides, #/ton	0.037	-	-	>0.037

The Best Practicable Treatment, based on several years of operating experience in coke plants, is probably biological oxidation of the plant effluent, after reduction of the effluent volume to a optimally minimum volume. The U.S.G.S. survey data indicate that 50% of the coke plants practicing recirculation of cooling water discharge effluents of less than 311 gals. per ton of coal, the average being 474 gals. per ton of coal. A total effluent volume of 300 gals. per ton of coal should thus be easily achievable. For the average coke plant coking 5,328 tons of coal per day, the effluent volume would be 1.6 mgd. The concentrations in the effluent would be:

Parameter	Load, #/day	Concentration, ppm
Phenol	575	43
Cyanide	155	12
Ammonia	400	30
Thiocyanate	639	48
B.O.D.	3149	236
Dissolved Solids	8562	642
Chlorides	7230	542
Suspended Solids	1162	87
Sulphates	1039	78
Sulfides	197	15

The average effluent concentrations or minimum percentage reductions reported for the Brookhouse plant, which treats ammonia still wastes rather than flushing liquor, provide performance criteria. The criteria for cyanides and suspended solids are taken from the Spencer plant and are conservative. Sulfides are assumed converted to sulfates and other inorganics are assumed to be unchanged. The effluent loads for the plant coking 5,328 tons of coke per day and treating 1.6 mgd biologically would be:

Parameter	Influent, ppm	Effluent, ppm or % Reduction	Effluent, #/day	Effluent, #/ton
Phenol	43	1.5 ppm (1)	20.0	0.004
Cyanide	12	0.3 ppm (2)	4.0	0.001
Ammonia	30	7% (1)	372	0.070
Thiocyanate	48	2.5 ppm (1)	33.3	0.006
B.O.D.	236	86.2% (1)	434	0.081
Dissolved Solids	642	642	8562	1.607
Chlorides	542	542	7230	1.357
Suspended Solids	87	60 ppm (2)	800	0.150
Sulphates	78	123 ppm	1639	0.308
Sulfides	15	0	0	-

---

(1) Brookhouse

(2) Spencer

The Best Available Treatment is the distillation/incineration system presently installed at Alan Wood Steel Company. The system of the Armco plant in Houston is similar in that the waste waters are completely incinerated. If such treatment were installed, the optimum implementation would obviously be to reduce the waste water volume to a minimum. The U.S.G.S. data indicate that cooling waters effluents can be reduced to 58 gals. per ton of coal. The average benzol plant waste waters at Weirton and at Clairton (including the keystone, light oil, and tar plants in the latter) is 18.9 gals. per ton of coal. Adding the still wastes at 39.7 gals. per ton and the final cooler bleed at 6.9 gals. per ton, a total effluent volume of 123.5 gals. per ton of coat should be readily achievable. For a coke plant coking 5,328 tons of coal per day, the effluent volume would be 658,000 gpd. The distillation process would produce an effluent as follows in 96% of the original volume, or 632,000 gpd:

Ammonia	15 ppm
Thiocyanates	10 ppm
Oils	5 ppm
Phenols	10 ppb
Cyanides	10 ppb
Total Solids	10 ppm

The dissolved solids, concentrated in 26,320 gpd would be incinerated, spray dried, lead filled, or disposed of on ore piles, slag quenching, or slag piles.

The Best Available Treatment effluent load would thus be:

Parameter	Volume or Concentration	#/day	gal.#/ton coal
Flow	632,000 gpd	-	119 gal.
Phenol	0.010 ppm	0.053	neg.
Cyanide	0.010 ppm	0.053	neg.
Ammonia	15 ppm	79.0	0.015
Thiocyanate	10 ppm	52.6	0.010 (3)
B.O.D. (1)	118 ppm	621	0.117 (3)
Dissolved Solids (2)	9 ppm	47.4	0.009
Suspended Solids (2)	1 ppm	5.3	0.001

---

(1) As ammonia reduction percent

(2) Proportionate parts of 10 ppm total solids

(3) No reduction

Summarzing the treatment levels:

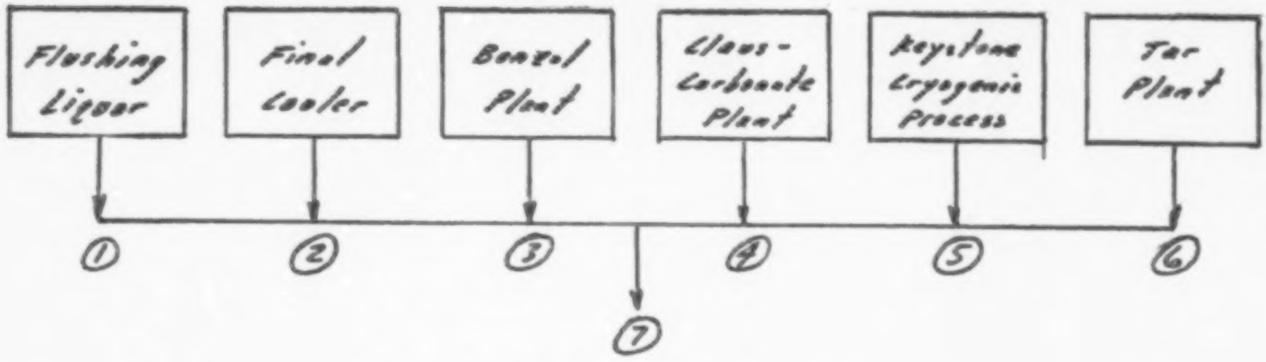
Parameter	SRWL	PRWL	BLT	BPT	BAT
Flow, gal./ton	4255	2862	2862	300	119
Phenol, #/ton	0.565	0.581	0.108	0.004	neg.
Cyanide, #/ton	1.225	0.064	0.029	0.001	neg.
Ammonia, #/ton	6.921	1.602	0.075	0.070	0.015
Thiocyanate, #/ton	4.247	0.265	0.120	0.006	0.006
B.O.D., #/ton	7.722	1.473	0.591	0.081	0.081
Chlorides, #/ton	1.353	1.175	1.357	1.357	-
C.O.D., #/ton	15.4	2.946	-	-	-
Sulfide, #/ton	0.187	0.168	0.037	-	-
Ferrocyanide, #/ton	0.005	-	-	-	-
Pyridine, #/ton	0.144	-	-	-	-
Thiosulfate, #/ton	0.054	-	-	-	-
Dissolved Solids, #/ton	-	3.802	1.607	1.607	0.009
Oil and Tar, #/ton	-	0.563	-	-	neg.
Suspended Solids, #/ton	-	0.053	0.218	0.150	0.001
Sulphates, #/ton	-	1.278	0.195	0.308	-

Figure 5 through 13 shows various coke plant configurations and lists the estimated process flows and the waste components that would be found in a given type Coke Plant Operation.

FIGURE 5

TYPE 1 COKE PLANT OPERATION

No Flushing Liquor Processing
Closed Final Cooler
Benzol Plant
Claus-Carbonate Plant
Keystone Cryogenic Process
Tar Plant



Waste Stream	Flow, gal. per ton coal
1	54.9
2	0
3	5.0
4	2.5
5	1.57
6	14.4
7	78.4

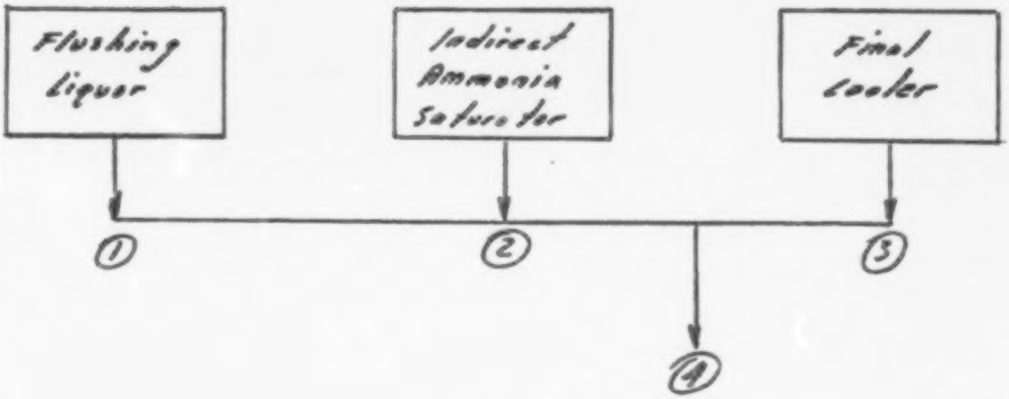
Waste Stream 7

Phenol, #/ton coal	0.659
Cyanide, #/ton coal	0.063
Ammonia, #/ton coal	1.913
Thiocyanate, #/ton coal	0.458
Sulfide, #/ton coal	0.329
Oil and Tar, #/ton coal	0.659
Dissolved Solids, #/ton coal	3.418
Sulfates, #/ton coal	0.847
Carbonates, #/ton coal	1.066
Chlorides, #/ton coal	1.098

FIGURE 6

TYPE Z COKE PLANT OPERATION

No Flushing Liquor Processing
Indirect Ammonia Saturator
Closed Final Cooler
No Benzol Plant



Waste Stream	Flow, gal. per ton coal
1	23.8
2	60.6
3	0
4	84.4

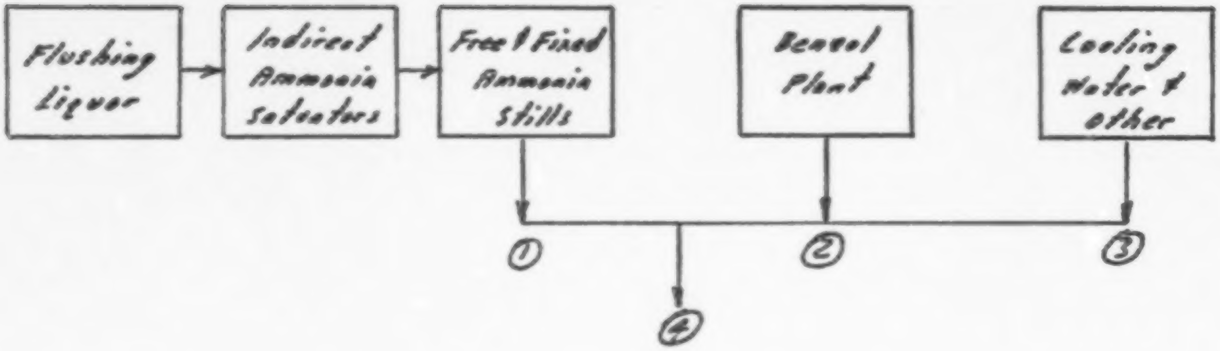
Waste Stream 4

Phenol, #/ton coal	1.511
Cyanide, #/ton coal	0.039
Ammonia, #/ton coal	3.515
Thiocyanate, #/ton coal	0.193
Oil and Tar, #/ton coal	0.021
Dissolved Solids, #/ton coal	5.975
Suspend Solids, #/ton coal	0.053

FIGURE 7

TYPE 3 COKE PLANT OPERATIONS

Indirect Ammonia Recovery
Free and Fixed Ammonia Stills
Benzol Plant
No Final Cooler
Indirect Cooling Water Included



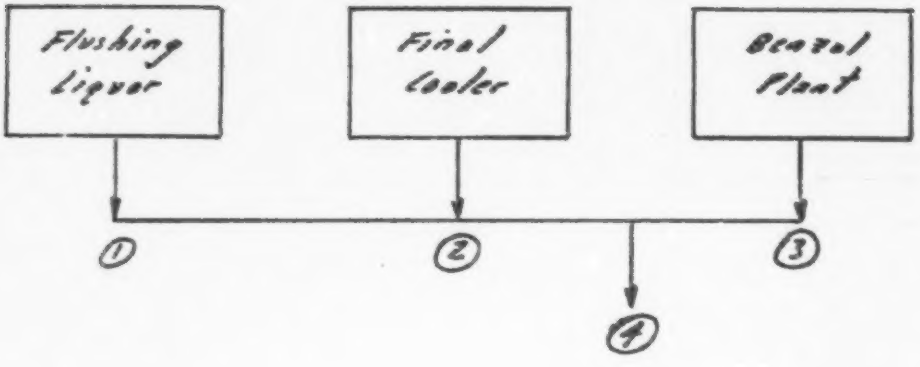
Waste Stream	Flow, gal. per ton coal
1	64
2	–
3	–
4	3560

	Waste Stream 1	Waste Stream 4	Waste Stream 2
Phenol, #/ton coal	0.398	0.405	0.001
Cyanide, #/ton coal	0.004	0.005	0.005
Ammonia, #/ton coal	0.055	0.065	0.010
Thiocyanate, #/ton coal	0.500	0.490	–
B.O.D., #/ton coal	1.400	1.800	–
Sulfide, #/ton coal	0.030	–	–
Chloride, #/ton coal	1.700	–	–

FIGURE 8

TYPE 4 COKE PLANT OPERATIONS

No Flushing Liquor Processing
Once-Through Final Cooler
Benzol Plant



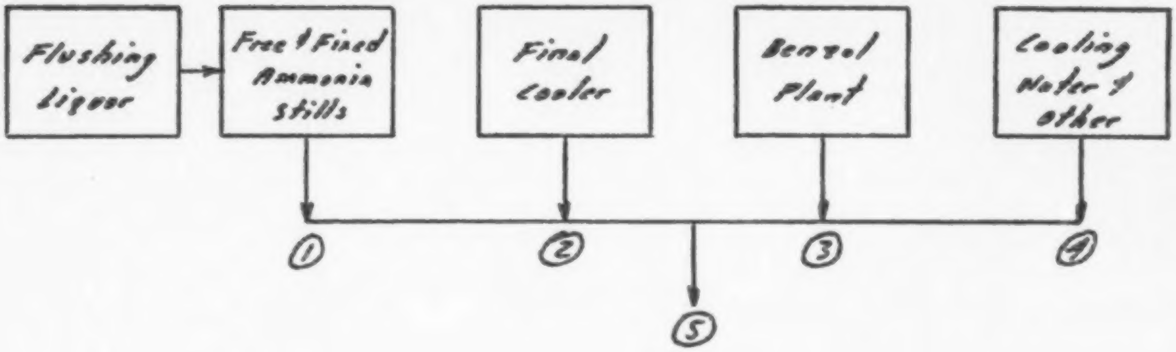
Waste Stream	Flow, gal. per ton coal
1	20.9
2	910
3	68.3
4	999

	Waste Stream			
	1	2	3	4
Phenol, #/ton coal	0.303	0.079	0.002	0.384
Ammonia, #/ton coal	0.921	5.527	0.003	6.451
Cyanide, #/ton coal	0.005	1.183	0.006	1.194
Sulfur, #/ton coal	–	–	–	0.168

FIGURE 9

TYPE 5 COKE PLANT OPERATIONS

Semi-Direct Ammonia Recovery
Free and Fixed Ammonia Stills
Closed Final Cooler
Benzol Plant
Indirect Cooling Water Included



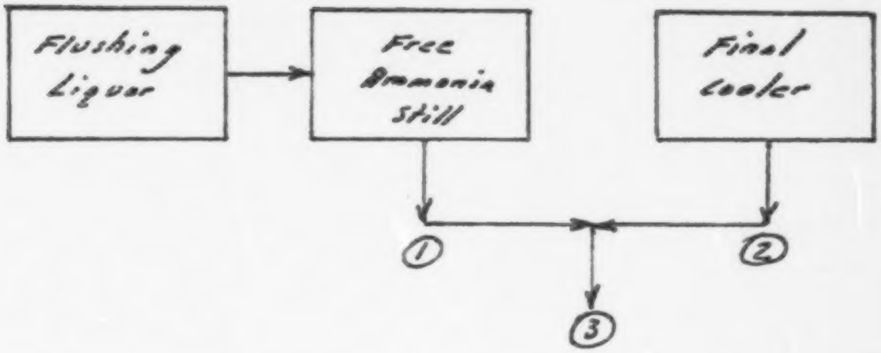
Waste stream	Flow, gal. per ton coal
1	33
2	0
3	–
4	–
5	1650

	Waste stream		
	1	3	5
Phenol, #/ton coal	0.230	0.007	0.340
Cyanide, #/ton coal	0.001	0.002	0.008
Ammonia, #/ton coal	0.080	0.001	0.100
Sulfur, #/ton coal	0.008	–	–
B.O.D., #/ton coal	0.470	–	1.300
Chlorides, #/ton coal	1.800	–	–

FIGURE 10

TYPE 6 COKE PLANT OPERATIONS

Semi-Direct Ammonia Recovery
Free Ammonia Still
Once-Through Final Cooler
No Benzol Plant



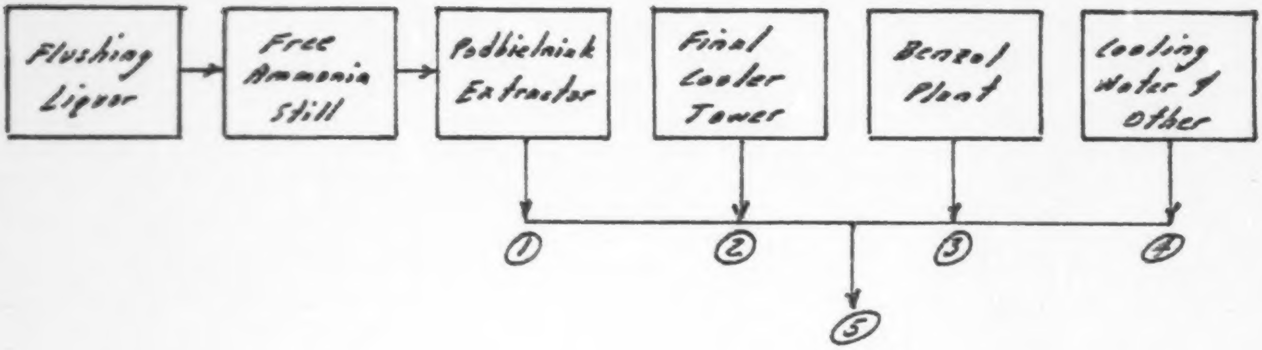
Waste Stream	Flow, gal. per ton coal
1	20
2	1400
3	1420

	Waste Stream 1	Waste Stream 2	Waste Stream 3
Phenol, #/ton coal	0.072	0.058	0.132
Cyanide, #/ton coal	0.0004	1.866	1.850
Ammonia, #/ton coal	0.870	–	0.920
Thiocyanate, #/ton coal	0.240	–	–
B.O.D., #/ton coal	0.370	5.773	6.150

FIGURE 11

TYPE 7 COKE PLANT OPERATIONS

Semi-Direct Ammonia Recovery
Free Ammonia Still
Final Cooler Cooling Tower Bleed
Podbielniak Dephenolizer
Benzol Plant
Indirect Cooling Water Included



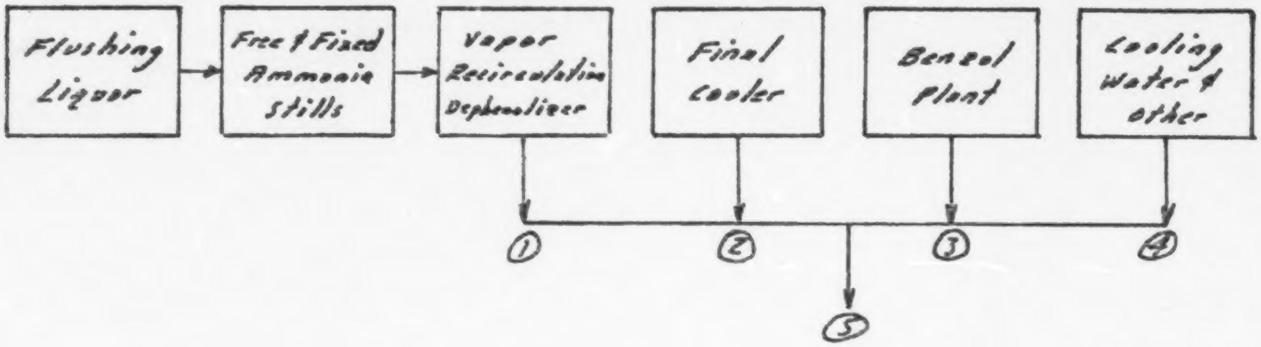
Waste Stream	Flow, gal. per ton coal
1	20.8
2	10.4
3	16.8
4	2375
5	2423

	Waste Stream			
	1	2	3	5
Phenol, #/ton coal	0.040	0.115	0.031	0.264
Ammonia, #/ton coal	-	0.040	0.003	0.817
Cyanide, #/ton coal	0.037	0.010	0.003	0.112
B.O.D., #/ton coal	0.186	0.235	0.052	0.606
Chlorides, #/ton coal	-	-	-	1.536
Oil, #/ton coal	-	-	-	0.085
Sulphates, #/ton coal	-	-	-	3.296

FIGURE 12

TYPE 8 COKE PLANT OPERATIONS

Semi-Direct Ammonia Recovery
Free and Fixed Ammonia Stills
Vapor Recirculation Dephenolizer
Closed Final Cooler
Benzol Plant
Indirect Cooling Water Included



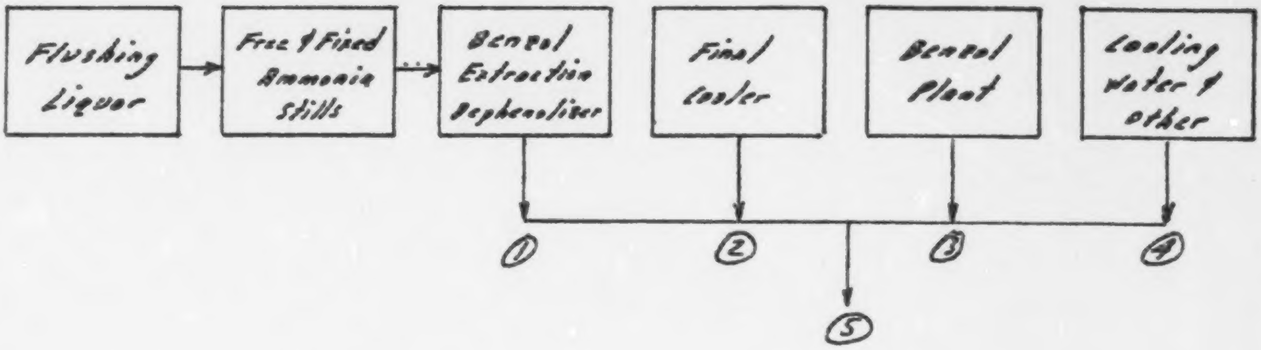
Waste Stream	Flow, gal. per ton coal
1	21
2	0
3	-
4	-
5	2960

	Waste Stream		
	1	3	5
Phenol, #/ton coal	0.007	0.011	0.048
Ammonia, #/ton coal	0.006	0.062	0.062
Cyanide, #/ton coal	0.005	0.003	0.009
Thiocyanate, #/ton coal	0.057	-	-
B.O.D., #/ton coal	0.150	-	-
Sulfide, #/ton coal	0.069	-	-

FIGURE 13

TYPE 9 COKE PLANT OPERATIONS

Semi-Direct Ammonia Recovery
Free and Fixed Ammonia Stills
Benzol Extraction Dephenolizer
Closed Final Cooler
Benzol Plant
Indirect Cooling Water Included



Waste Stream	Flow, gal. per ton coal
1	23
2	0
3	-
4	-
5	860

	Waste Stream		
	1	3	5
Phenol, #/ton coal	0.007	0.006	0.0140
Ammonia, #/ton coal	0.014	-	0.010
Cyanide, #/ton coal	0.003	0.002	0.005
Thiocyanate, #/ton coal	0.066	-	0.067
Sulfide, #/ton coal	0.004	-	-

COSTS OF WASTE TREATMENT METHODS

Base Level of Treatment:

There is considerable doubt as to whether or not the costs associated with the operation of ammonia stills should be considered to be pollution abatement costs. Stills were operated for many years as part of normal production and have only been eliminated or not operated because of the dwindling market for ammonium sulfate, principally due to competition from synthetic ammonia. Many plants still produce and sell ammonium sulfate and at least one plant produces anhydrous ammonia.

In 1955, ammonium sulfate sold for $42 per ton f.o.b. sulfuric acid at the time cost about $23.50 per ton. Ammonium sulfate, production at that time was at least marginally profitable. It can be inferred from the reported work by Bethlehem Steel Corp. that ammonia stills for a plant coking 4,800 tons of coal per day would cost less than $700,000 (1972).

Assuming the production of 25 lbs. of ammonium sulfate per ton of coal, the "average" coke plant would produce 133,200 lbs., or 67 tons of ammonium sulfate per day, using 50 tons of sulfuric acid. The net daily cost would have been $1,639 in 1955. On the basis of the M&S equipment cost index, 1972 comparative costs would be about $2,810 per day (1955 = 190.6; 1972 = 326.8), or $1,026,000 per year.

The ammonia in the flushing liquor is about 20% of the total. The cost associated with the operation at the ammonia stills would thus be about $562 per day, or $205,130 per year. Taking the capital cost of the stills at $\frac{5328}{4800}$ x $700,000, or $777,000, at 10% for 20 years, the annualized capital cost would be $91,266, or $250 per day.

Costs may thus be estimated as follows for a plant coking 5,328 tons of coal per day:

Capital Costs: $777,000 = $146 per ton of coal per day

Operating Cost: $113,880 per year = $0.06 per ton of coal coked

A dephenolizer, in 1950, for a plant carbonizing 3,600 tons of coal per day cost $225,000. Based upon the M&S Index, the 1972 cost for a plant coking 5,328 tons of coal per day would be:

$$\left(\frac{5328}{3600}\right)^{0.6}\left(\frac{326.8}{167.9}\right) \times (\$225,000) = \$554,000$$

or $104 per ton of coal per day

Given the fact that the value of sodium phenolate has decreased over the years, the value of the product should at least cover the operating costs other than depreciation, i.e., be zero.

Best Practicable Treatment:

The Bethlehem Steel bio-oxidation plant at Bethelhem, Pa. cost $310,000 and has a hydraulic capacity of 450,000 gpd. On the basis of the ENR Construction Cost Index (1962 = 900; 1972 = 1700) and a size exponent of 0.6, a plant to handle 1.6 mgd would cost:

$$\left(\frac{1,600,000}{450,000}\right)^{0.6} \frac{1700}{900} \quad (\$310,000) = \$1,171,000$$

The operating costs of such a facility costing $732/1,000 gpd would be about $116/yr/1000 gpd, or $185,600 per year (organic profile).

Costs then for a plant coking 5,328 tons of coal per day would be:

Capital Costs: $1,171,000 = $220 per ton of coal per day

Operating Costs: $185,600 per year = $0.095 per ton of coal coked

Best Available Treatment:

The cost of the distillation/incineration system installed of Alan

Wood Steel Company was $1.8 million. This plant handles 180,000 gpd. The comparable cost for the "average" coke plant would be:

$$\left(\frac{658,000}{180,000}\right)^{0.6} (1.8 \text{ million}) = \$3.92 \text{ million}$$

This is a maximum figure based upon the first, non-optimized plant. Operating costs are estimated at $1.75 per 1000 gal., or $1152 per day, taking no credit for product water.

Costs then for a plant coking 5,378 tons of coal per day would be:

Capital Costs: $3.92 million = $736 per ton of coal per day

Operating Costs: $420,300 per year = $0.216 per ton of coal coked

COKE QUENCHING WITH WASTEWATER

The use of wastewaters to quench coke superficially results in elimination of the potential water pollution so long as the water system is operated on a closed cycle with no overflow to the sewer. Such a system is shown in Figure 1. Many references to the use of such a disposal method point out that corrosion of metal surfaces result and that an air pollution problem is created.

Black, et al., (5) states: "Quenching coke with wastewaters is beset with other objectionable features. The corrosive effect of these wastes, because of their chloride content, is apparent on all metal surfaces with which they come in contact. Such damage, though difficult to assess monetarily, must be charged to this method of waste disposal. The contaminated vapors emanating from the quench tower may create an air pollution problem in a congested or built-up area."

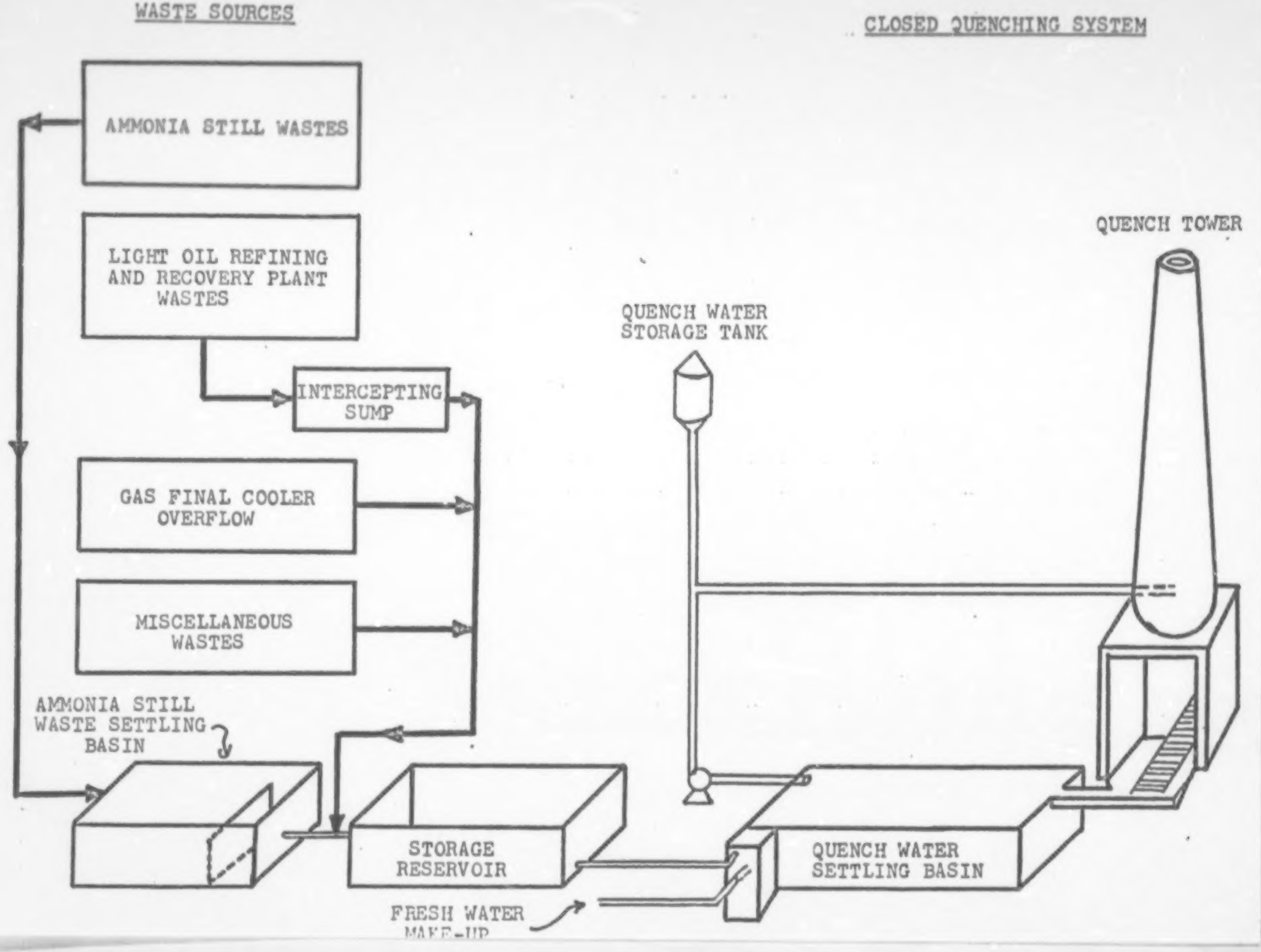
In referring to the disposal of contaminated wastes by coke quenching, the Steel Industry Action Committee of the Ohio River Valley Water Sanitation Commission (6) stated: "With this method the quenching system must be a closed system. Numerous objections to this method may be cited. It is quite expensive due to the corrosion of coke handling and adjacent plant equipment ... In addition to the corrosion problem this method presents an air pollution problem and cannot be used where plants are located in densely populated areas."

Commenting on coke quenching with still wastes, Muns and Thompson (6A) stated: "The main objection to this practice is that the calcium chloride in the wastes tends to build up in the system, and creates a serious corrosion problem to equipment and surrounding steel structures."

Coke quenching at the Bethlehem Plant of Bethlehem Steel Corporation cost more than $240,000 per year for replacement of structural steel at and in the vicinity of the quench station and for repair of quench cars (7). This plant has 376 ovens. "Successful biological treatment of WAL (weak ammonia liquor) in a full-scale plant has produced the following beneficial results: 1. The need for the costly practice of quenching coke with WAL has been eliminated at the Bethlehem Plant. 2. Air pollution from WAL in the area of the quench station has been eliminated completely."

Dominion Foundries and Steel of Hamilton, Ontario decided to install a flushing liquor treatment system (8) that "... this method (coke quenching with flushing liquor) would contribute to inplant air pollution and to the corrosion of steel in the vicinity of the quencher station." This plant has 239 coke ovens.

FIGURE 14- Schematic Diagram of a Coke Quenching System for Disposing of all Liquid Wastes


WASTE SOURCES
CLOSED QUENCHING SYSTEM
AMMONIA STILL WASTES
LIGHT OIL REFINING AND RECOVERY PLANT WASTES
INTERCEPTING SUMP
GAS FINAL COOLER OVERFLOW
MISCELLANEOUS WASTES
AMMONIA STILL WASTE SETTLING BASIN
STORAGE RESERVOIR
FRESH WATER MAKE-UP
QUENCH WATER STORAGE TANK
QUENCH WATER SETTLING BASIN
QUENCH TOWER

In discussing the disposal of coke plant waste to the sanitary sewer system of Gary, Indiana, J. M. Muller of U. S. Steel Corporation stated (9): "It was expected that if ammonia liquor could be handled by the City Plant, then 100 percent fresh-water quenching could be initiated which would result in reduced corrosion in the Sinter Plant and Coke Plant. (3). The blast furnace water pollution caused by the liquor in the coke would be eliminated."

It is quite apparent that the use of wastewaters for coke quenching is not an acceptable means of disposal. The air pollution which results is well documented, if not obvious, and the corrosion damage alone would justify costs of alternative treatment.

Unless the blast furnace gaswasher water where this coke is used is a 100% closed recycle system, water pollution will result from the liquor retained by the coke (9). Experimental results by Black (5) have shown the following correlation between phenols in the coke quench water and in blast furnace gaswasher water:

$$\text{ppm phenol in washer water} = 0.26 + \left(\frac{\text{ppm phenol in quench water}}{455}\right)$$

then with 547 ppm phenol in the quench water:

$$\text{ppm phenol in washer water} = 0.26 + \left(\frac{547}{455}\right) = 1.46 \text{ ppm}$$

Assuming the use of 3,000 gpm of gaswasher water in a blast furnace producing 2,000 tons of iron per day and the use of 0.6 tons of coke per ton of iron, the phenol discharged from blast furnaces utilizing this coke would be:

$$3{,}000 \times 1440 \times 8.33 \times 10^{-6} \times 1.46 \times \left(\frac{22007}{1200}\right) = 961 \text{ lbs. per day}$$

The dissolved solids in the quench water are simply transported into the air environment, deposited on land and structures, and eventually washed into the surface waters. Most of the other constituents that are not absorbed onto the coke follow a similar pathway into surrounding surface waters. Steam distillation and mechanical carryover in the evaporated water probably account for the transport mechanism.

There is little to justify coke quenching as a wastewater disposal method. Not only do air pollution and corrosion result, but water pollution is not really abated to any significant extent.

WASTEWATER TREATMENT METHODS

There are many alternative methods by which the wastewaters from coke plant operations can be treated, all of which have been demonstrated in operating coke plants. The following represents a listing of the alternative processes and plants known to have utilized each, or where such processes are being constructed or have been proposed for use by the operator of the plant:

1. Co-Treatment in Municipal Sewage Treatment Plants
   - U. S. Steel Corporation, Gary, Indiana
   - Inland Steel Compnay, East Chicago, Indiana
   - Youngstown Sheet and Tube Company, East Chicago, Indiana
   - Republic Steel Corporation, Chicago, Illinois
   - Interlake Steel Corporation, Chicago, Illinois
   - Wisconsin Steel Div., International Harvester Company, Chicago, Illinois
2. Biological Treatment (In-Plant)
   - Granite City Steel Company, Granite City, Illinois
   - Bethlehem Steel Company, Bethlehem, Pennsylvania
   - Dominion Foundries and Steel , Hamilton, Ontario
   - British Steel Corporation, Midland Group, Brookhouse Coke Oven Plant
   - British Steel Corporation, Midland Group, Spencer Works Coke Oven Plant
   - Weirton Steel Division, National Steel Corporation, Weirton, West Virginia
   - U. S. Steel Corporation, Fairfield, Alabama
   - U. S. Steel Corporation, Clairton, Pennsylvania

3. Deep-Well Disposal

   Bethlehem Steel Company, Burns Harbor, Indiana

4. Distillation/Incineration

   Armco Steel Corp., Houston, Texas

   Alan Wood Steel Company, Conshohocken, Pennsylvania

5. Solvent Extraction

   Weirton Steel Company, Weirton, West Virginia

   Jones and Laughlin Steel Corporation, Pittsburgh, Pa.

Additionally, the use of carbon absorption and calalytic oxidation has been demonstrated on a pilot plant basis with coke plant wastes sufficiently for full-scale plant design (10). Carbon absorption has also been successfully used on chemical plant wastes containing phenols in a plant treating 150,000 gpd (11). Chemical treatment is known to be an effective treatment method (6).

BLAST FURNACE OPERATIONS

Molten iron for subsequent steelmaking operations is normally produced in a blast furnace. The blast furnace is a vertical, quasi-cylindrical structure, ranging from 65 to 106 feet high and 15 to 28 feet in diameter. The blast furnace process consists essentially of charging iron ore, limestone, and coke into the top of the furnace and blowing heated air into the bottom. Combustion of the coke provides the heat necessary to obtain the temperature at which the metallurgical reducing reactions take place. Incandescent carbon of the coke accounts for about 20 percent of the reduction of the iron oxides; carbon monoxide formed between the coke and oxygen of the blast accounts for the remaining reduction accomplished. The function of the limestone is to form a slag, fluid at the furnace temperature, which combines with unwanted impurities in the ore. Two tons of ore, one ton or less of coke, one-half ton of limestone, and three and one-half tons of air produce approximately one ton of iron, one-half ton of slag, and five tons of blast furnace gas containing the fines of the burden carried out by the blast; these fines are referred to as flue dust. Molten iron is periodically withdrawn from the bottom of the furnace;the fluid slag which floats on top of the iron is also periodically withdrawn from the furnace. Blast furnace flue gas has considerable heating value and is burned to preheat the air blast to the furnace.

The blast furnace auxiliaries consist of the stoves in which the blast is preheated, the dry dust catchers in which the bulk of the flue dust is recovered, primary wet cleaners in which most of the remaining flue dust is removed by washing with water, and secondary cleaners such as electrostatic precipitators.

The water used in washing blast furnace flue gas free of dust particles contains from 1,000 to 10,000 mg/liter of suspended solids, which approximate the composition of the furnace burden. Following a slip in the furnace, the concentration of suspended solids may be as much as 30,000 mg/liter. Blast furnace gaswasher water may amount to 600 to 5,000 gallons per minute per furnace, depending upon the type of washer used. The suspended solids from an iron-producing furnace are generally 50 percent finer than 10 microns in diameter and have a specific gravity of about 3.5 on the average; the effluent is red in color. A furnace producing ferromanganese discharges particles which are extremely fine and are lighter in color than those from as iron-producing furnace.

Blast furnace gaswasher water contains significant concentrations of cyanides, phenol, and ammonia in addition to suspended solids. Gaswasher waters from ferromanganese furnaces have much higher concentrations of cyanides than do washwaters from iron furnaces.

These wastewaters result from a gas -cleaning operation, and thus prevent to a considerable extent air pollution which would otherwise result. The primary reason for cleaning the gas, however, is to allow its use as a fuel. Cooling blast furnace slag produces quantities of water containing slag particles. The effluent from a slag pit may range from 100 to 200 gallons per minute and is of a clear appearance. Air cooled slag is produced by spraying a limited amount of water on molten slag to accelerate cooling into a solid mass which is dugout with power shovels. Granulated slag is produced by pouring molten slag into a water filled pit and additionally spraying the molten stream; the rapid cooling causes the slag to expand and break into small particles.

The blast furnace requires the continuous circulation of cooling water through hollow plates built into the walls of the bosh and stack. Without such cooling, a furnace wall would quickly burn through. Additional water is used in the boiler house, turbine condensers, etc.

The water use in a particular single-furnace blast furnace shop producing 2,500 tons of pig iron per day is as follows:

Furnace Cooling Water	21,000 gpm	12,096 gal./ton
Gaswasher Water	3,700 gpm	2,131 gal./ton
Boiler House and Other	21,226 gpm	12,226 gal./ton
Total	45,926 gpm	26,453 gal./ton

The suspended solids in blast furnace gaswasher water result from the fines in the burden being carried out in the gas. The quantities depend upon the operation of the furnace and the nature of the burden, i.e., friability nature of the ore, pellets, or sinter; particle size of the limestone, etc. Oils can be vaporized and carried into the gas when metal turnings are part of the charge. Phenols, cyanides, and ammonia orginate in the coke and are particularly high if the coke has been quenched with waste waters or if the coke is "green", i.e., has not been completely coked. Cyanides are generated in the blast furnace in the reducing atmosphere from carbon from the coke and nitrogen from the air; cyanide formation is particularly high at the higher temperatures of a ferromanganese furnace.

The 1970 edition of the American Iron and Steel Institute publication entitled "Directory of Iron and Steel Works of the United States and

Canada" indicates the availability of 218 blast furnaces which are tabulated in Table X . The total number of blast furnaces producing pig iron and ferroalloys in the United States has decreased from 250 in 1960 to 219 as of January 1, 1971. As shown below, data from the 1970 Annual Statistical Report of the American Iron and Steel Institute indicates that only about 71.2% of the available blast furnaces are operated in any given year.

Year	Total Blast Furnaces	Total In Blast	% In Blast
1967	232	164	70.6
1968	230	173	75.2
1969	230	154	66.9
1970	228	169	74.1
1971	219	152	69.4
		Average	71.2

The blast furnaces not in blast were either being relined, rebuilt or unnecessary because of age on production level. In Table VIII, the distribution of blast furnaces by state and company is shown. It may be noted that with the exception of Kentucky (two blast furnaces) and Tennessee (44 coke ovens), all blast furnaces and coke ovens are located in the same fourteen states. The 1970 production of Pig Iron and Ferroalloys was 93,851,000 net tons and is shown below by state.

State	Pig Iron	Ferroalloys	Total
Pennsylvania	20,768,000	395,000	21,163,000
Ohio	15,554,000	901,000	16,455,000
Indiana	13,348,000	-	13,348,000
Illinois	7,401,000	-	7,401,000
New York	5,569,000	69,000	5,638,000
Alabama	4,654,000	-	4,654,000
Other States	24,141,000	1,051,000	25,192,000
Total	91,435,000	2,416,000	93,851,000

TABLE VIII DISTRIBUTION OF BLAST FURNACES BY STATE

COMPANY	Pa.	Ohio	Ind.	Ill.	Ala.	N.Y.	Md.	Mich	Colo	Ca.	W.Va	Utah	Ky.	Tex.	Minn	Total
Alan Wood Steel Company	2															2
Armco Steel Corporation		3											2	1		6
Bethlehem Steel Corp.	9		2			7	10									28
C.F. & I. Corporation									4							4
Crucible Steel Inc.	2															2
Detroit Steel Corporation		2														2
Ford Motor Company								3								3
Granite City Steel Corp.				2												2
Inland Steel Company			8													8
Interlake, Inc.	1	2		2												5
Wisconsin Steel				3												3
Jones & Laughlin Steel	11	3														14
Kaiser Steel Corporation										4						4
Lone Star Steel Corp.														1		1
McLauth Steel Corp.								2								2
National Steel Corp.								4			4					8
Hanna Furnace Corp.						3										3
Republic Steel Corp.		13		1	4	3										21
Sharon Steel Corporation	2															2
Shenango, Inc.	3															3
Tonawanda Iron Div.						1										1
U.S. Pipe & Foundry Co.					3											3
U. S. Steel Corp.	22	11	12	11	8							3			2	69
Wheeling Pittsburgh Steel	3	5														8
Woodward Company					4											4
Youngstown Sheet & Tube		6	4													10
TOTAL	55	45	26	19	19	14	10	9	4	4	4	3	2	2	2	218

While producing 91,435,000 net tons of pig iron, 150 blast furnaces or 69.1% of the total available where in blast 55,697 days with an average production of 1,641.6 tons per furnace per day. Of the 2,416,000 net tons of ferroalloy production, only 381,000 or 15.8% was produced in blast furnaces, the remaining was produced in electric furnaces and is shown below by grade.

Source and Grade	Production, net tons	% of total production
Blast Furnaces:		
Ferromanganese and spiegel	381,000	15.8
Electric Furnaces:		
Ferromanganese	415,000	17.1
Ferrosilicon	550,000	22.8
Ferrochrome	275,000	11.4
Ferrochrome Silicon	165,000	6.8
Ferrophosphorus	114,000	4.7
Silico-manganese	246,000	10.2
All others	270,000	11.2
Total	2,416,000	100.0

Thus with only two blast furnaces indicated to be available for ferroalloy production in the AISI Statistical Report 1970 average production per furnace was 190,500 tons/year or 522 tons per day. From the tabulation of blast furnaces, three furnaces are indicated to produce Ferromanganese and are listed below.

Company	Plant	Capacity tons/day
Bethlehem Steel Corporation	Johnstown	1120
United States Steel Corporation	Clairton	1200
United States Steel Corporation	Fairfield	1200

From published data, as shown in Table VIII the pig iron production based upon working volume and hearth diameter is illustrated in Figure 15 and Figure 16 .

TABLE IX

Blast Furnace Production From Published Sources

Company	Plant	Furnace No.	Working Volume Cubic Feet	Hearth Dia.ft.in	Rated Capacity tons/day
Alan Wood Steel Co.	Swedeland	2	21,430	18-0	1,000
		3	20,700	18-0	1,000
National Steel Corp.	Weirton	1	39,887	27-0	1,700
		2	50,545	27-0	2,050
		3	47,030	25-6	1,850
		4	47,030	25-6	2,050
Jones & Laughlin Steel	Pittsburgh	P-1	28,600	22-0	1,200
		P-2	41,300	26-6	1,650
		P-3	54,400	29-0	2,100
		P-4	25,500	20-6	1,000
		P-5	23,100	19-3	900
Youngstown Sheet & Tube	Campbell	1	27,626	21-0	1,200
		2	31,226	21-6	1,200
		3	37,583	23-0	1,800
		4	37,583	23-0	1,800
United States Steel	Fairless	1	55,651	29-6	2,912
Jones & Laughlin Steel	Pittsburgh	P-6	35,400	26-6	1,400
CF & I Steel Corporation	Pueblo	A	32,000	22-9	800
		D	28,970	21-0	800
		E	24,656	21-6	800
		F	27,021	21-9	800
Republic Steel Corporation	South Chicago	1	54,400	28-0	2,500
Granite City Steel Company		B	46,893	28-0	1,900
Jones & Laughlin Steel	Aliquippa	A-2	56,600	29-0	2,500
Armco Steel Corporation	Houston	1	54,890	27-3	2,340
Youngstown Sheet & Tube	Indiana Harbor	Ellen	63,870	32-0	4,000
Bethlehem Steel Corporation	Sparrows Point	J	54,830	30-0	4,000
Steel Company of Canada		1	70,845	32-0	5,000
Bethlehem Steel Corporation	Burns Harbor	C	89,204	38-0	5,600
		D	85,750	35-0	5,000

Figure XV represents 24 blast furnaces, about 11% of the total available, which have hearth diameters of less than 30 ft and daily production of less than 3,000 tons. These furnaces are typical of pig iron production units presently operating in the United States. Of the total available blast furnaces tabulated in Table 210 or 96.3% are in this group. Figure XVI represents examples of the new and modern blast furnaces capable of producing over 5,000 tons per day. These furnaces have hearth diameters of greater than 30 ft., with working volumes between 55,000 and 90,000 cubic feet. However, new furnaces are just one method of increasing production, during relining or rebuilding of existing furnaces, the inner volume have been enlarged to increase productivity. Also improvements in the quality of raw materials, new process knowledge , and more efficient use of existing equipment have resulting in greator production. As an example, Inland Steel Company has reported daily production at one blast furnace reaching three times the design capacity. At the new Burns Harbor plant of Bethlehem Steel Company, productivity of the "D" furnace has reached a daily high of 5,531 tons while originally estimated at 5,000 tons. Alan Wood Steel Corporation has announced a first phase expansion from 1,000 to 1,400 tons with a future expansion to 2,000 ton/day for each furnace.

The productivity of U. S. blast furnaces is expected to continue to increase. The average production of pig iron per blast furnace should reach 2,200 ton by 1980. Tht total number of blast furnaces in operation is expected to continue to decrease as older and smaller furnaces are phased out. The decrease in total blast furnaces is shown below for the past five years.

Year	Number of Furnaces
1967	232
1968	230
1969	230
1970	228
1971	219

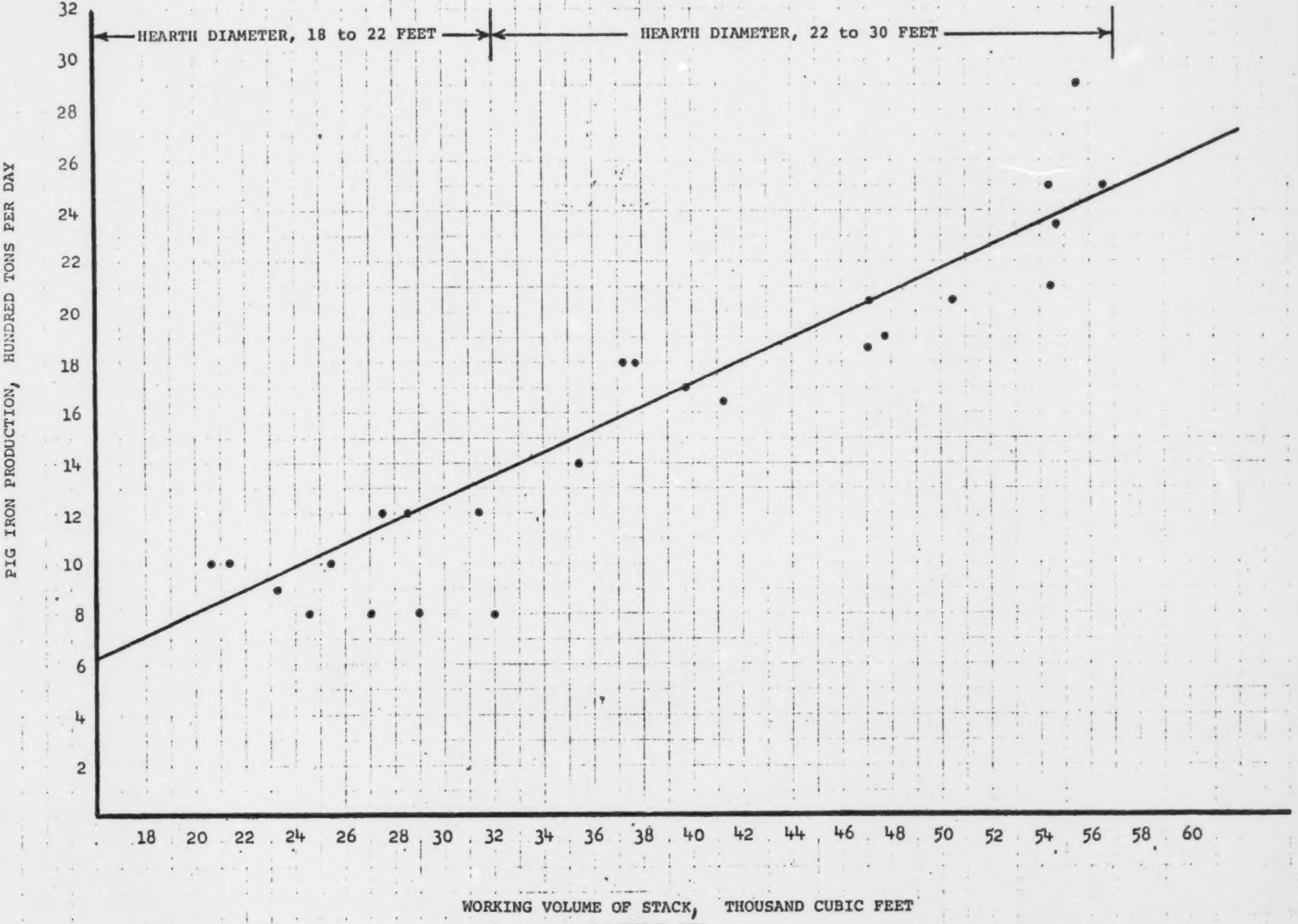

HEARTH DIAMETER, 18 to 22 FEET
HEARTH DIAMETER, 22 to 30 FEET
PIG IRON PRODUCTION, HUNDRED TONS PER DAY
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
WORKING VOLUME OF STACK, THOUSAND CUBIC FEET

FIGURE XV

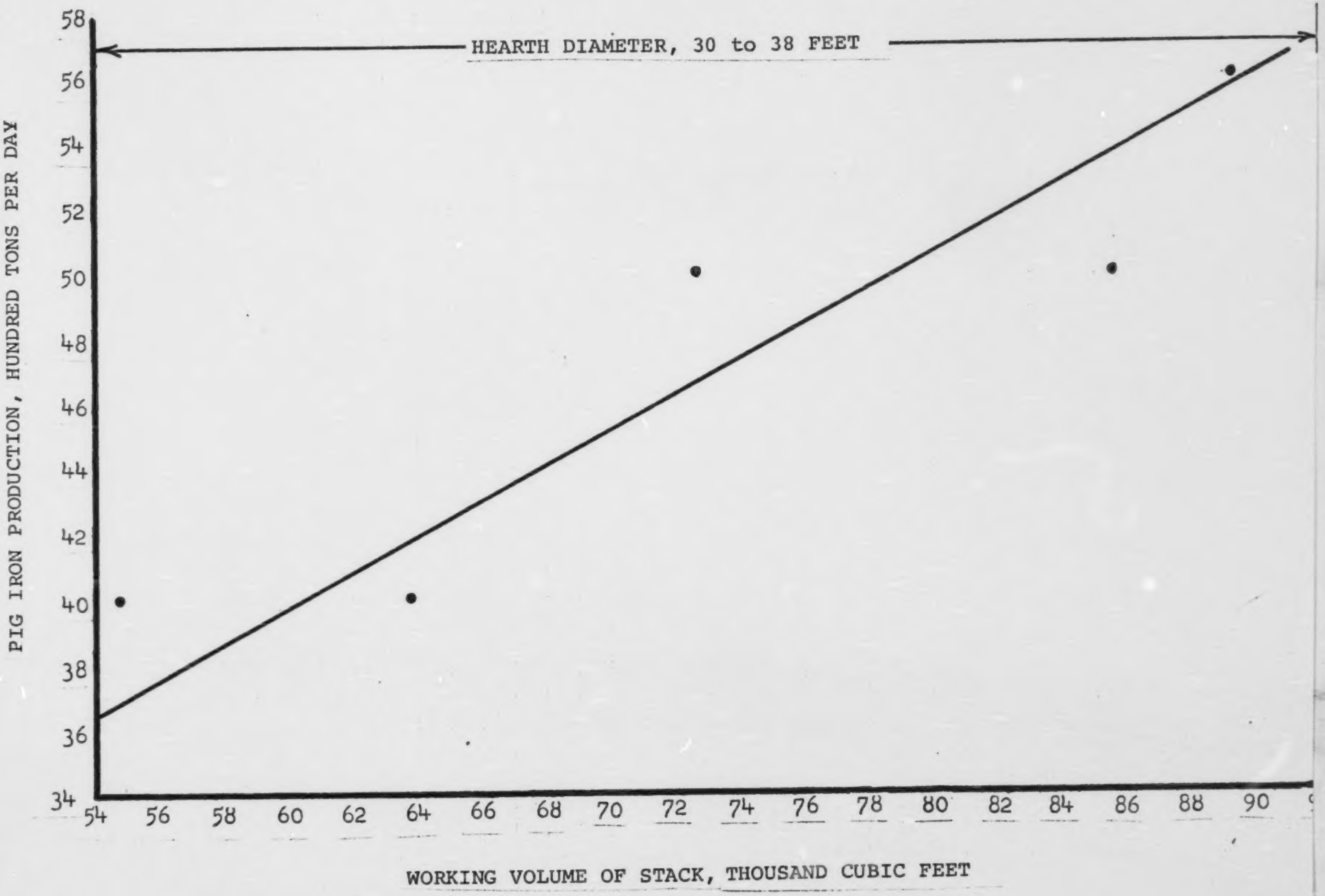

HEARTH DIAMETER, 30 to 38 FEET
PIG IRON PRODUCTION, HUNDRED TONS PER DAY
58
56
54
52
50
48
46
44
42
40
38
36
34
54
56
58
60
62
64
66
68
70
72
74
76
78
80
82
84
86
88
90
WORKING VOLUME OF STACK, THOUSAND CUBIC FEET

FIGURE XVI

TABLE X BLAST FURNACES IN THE UNITED STATES - 1970

PLANT NUMBER	COMPANY WITH BLAST FURNACE	PLANT NAME	STATE	BLAST FURNACE	HEARTH DIAMETER Ft-In.	WORKING VOLUME OF STACK cubic feet	GRADE PRODUCED	PRODUCTION tons/day	VENTURI SCRUBBER	GAS WASHER	PRECIPATATOR	ELECTRO-STATIC PRECIP-ATATOR	ORIFICE PLATE SCRUBBER	GAS COOLER	TOWER UNITS	DISINTE-GRATORS	SINTER MACHINES	SINTER GRATE AREA sq.ft.	PIG
1.	Alan Wood Steel Co.	Swedeland	Pa.	2	18-0	21430	Basic	1000*					1	1			3	698	1
	" " " "	"	"	3	18-0	20700	Basic	1000*					1	1					
2.	Armco Steel Corp.	Ashland	Ky.	Amanda	33-42	72000	Basic	4620	1	1	1	2					1	807	1
	" " "	"	"	Bellefonte	28-9	52538	Basic	2280	1		1	2							
3.	Armco Steel Corp.	Hamilton	Ohio	1	18-6	23686	Basic	960				3					1		
	" " "	"	"	2	18-0	27416	Basic	1150											
4	Armco Steel Corp.	Houston	Tex.	1	27-3	54890	Basic	2340*	1		1						1	536	1
5.	Armco Steel Corp.	Middletown	Ohio	1	29-6	55324	Basic	2420							1				1
6.	Bethlehem Steel Corp.	Bethlehem	Pa.	B	28-9	51665	Basic	2250	1			4			1		4	1934	
	" " "	"	"	C	27-11	49050	Basic-Bess.	2120	1			4			1				
	" " "	"	"	D	30-0	54834	Basic	2380	1			4			1				
	" " "	"	"	E	24-0	41068	Basic-Bess.	1770	1			4			1				
7	Bethlehem Steel Corp.	SPARROW PT.	MD.	A	25-6	38395	Basic	1680	3			15			1	8	6	3672	1
	" " "	"	"	B	25-6	38895	Basic	1680							1				
	" " "	"	"	C	28-0	42219	Basic	1820							1				
	" " "	"	"	D	28-0	42858	Basic	1850							1				
	" " "	"	"	E	19-9	24892	Basic	1020							1				
	" " "	"	"	F	19-9	24998	Basic	1040							1				
	" " "	"	"	G	28-0	47167	Basic	2040							1				

TABLE X (CON'T)

PLANT NUMBER	COMPANY WITH BLAST FURNACE	PLANT NAME	STATE	BLAST FURNACE	HEARTH DIAMETER Ft-In.	WORKING VOLUME OF STACK cubic feet	GRADE PRODUCED	PRODUCTION tons/day	VENTURI SCRUBBER	GAS WASHER	PRECI-PATATOR	ELECTRO-STATIC PRECIP-ATATOR	ORIFICE PLATE SCRUBBER	GAS COOLER	TOWER UNITS	DISINTE-GRATORS	SINTER MACHINES	SINTER GRATE AREA sq.ft.
7	Bethlehem Steel Corp	Sparrows Pt	MD.	H	28-9	50547	Basic	2200										
	" " "	"	"	J	30-0	54830	Basic	4000*										
	" " "	"	"	K	30-0	54830	Basic	3700										
8	Bethlehem Steel Corp.	Lackawanna	N.Y.	A	21-3	28455	Basic	1190				9	5		2	4	6	3672
	" " "	"	"	B	21-3	28423	Basic	1180										
	" " "	"	"	C	29-6	51164	Basic	2220										
	" " "	"	"	F	26-0	39614	Basic	1690										
	" " "	"	"	G	27-0	39991	Basic	1710										
	" " "	"	"	H	29-0	50985	Basic	2215										
	" " "	"	"	J	29-11	54907	Basic	2400										
9	Bethlehem Steel Corp.	Johnstown	Pa.	E	22-8	31210	Ferro-manganese	1320	7								2	1192
	" " "	"	"	G	26-0	33327	Basic	1420										
	" " "	"	"	H	26-0	47642	Basic	2050										
	" " "	"	"	K	21-3	29750	Basic	1260										
	" " "	"	"	L	28-0	48568	Basic	2100										
10	Bethlehem Steel Corp.	Burns Harbor	Ind.	D	35-0	85750	Basic	5000*	2									
	" " "	"	"	C	39-3	89204	Basic	5600*	2									
11.	C F & I Steel Corp.	Pueblo	Colo.	A	22-9	32000	Basic + Foundry	800*	1								1	
	" " " " "	"	"	D	21-0	28970	"	800*	1									
	" " " " "	"	"	E	21-6	24656	"	800*	1									

TABLE X (CON'T)

PLANT NUMBER	COMPANY WITH BLAST FURNACE	PLANT NAME	STATE	BLAST FURNACE	HEARTH DIAMETER Ft-In.	WORKING VOLUME OF STACK cubic feet	GRADE PRODUCED	PRODUCTION tons/day	VENTURI SCRUBBER	GAS WASHER	PRECI-PATATOR	ELECTRO-STATIC PRECIP-ATATOR	ORIFICE PLATE SCRUBBER	GAS COOLER	TOWER UNITS	DISINTE-GRATORS	SINTER MACHINES	SINTER GRATE AREA sq.ft.	FIG
11.	C. F. + I. Steel Corp.	Pueblo	Colo.	F	21-9	27021	Basic + Foundry	800 *	1										
12.	Crucible Inc.	Midland	Pa.	1	25-9	45370	Basic	1960		1	2								1
	" "	"	"	3	18-0	22783	Basic	940		1	1								
13.	Detroit Steel Corp.	Portsmouth	Ohio	1	18-10	26640	Basic	1110	1	1	1								1
	" " "	"	"	2	28-6	55725	Basic	2440		1	1								
14	Ford Motor Company	Rouge	Mich	A	20-0	28000	Basic	1170	1			2				1	1	576	1
	" " "	"	"	B	20-0	27400	Basic	1150	1							1			
	" " "	"	"	C	29-0	49000	Basic	2120	1							2			
15.	Granite City Steel Co.	Granite City	Ill.	A	26-6	42568	Basic	1820	1				1				1	1024	1
	" " " "	"	"	B	28-0	46893	Basic	2040											
16	Inland Steel Company	Indiana Harbor	Ind.	1	20-9	31196	Basic	1310	1							5	1	1312	1
	" " "	" "	"	2	19-9	24585	Basic	1050	1										
	" " "	" "	"	3	20-9	30770	Basic	1290	1										
	" " "	" "	"	4	20-9	28621	Basic	1200	1										
	" " "	" "	"	5	26-6	46325	Basic	2010	1										
	" " "	" "	"	6	26-6	47725	Basic	2070	1										
	" " "	" "	"	A	26-6	46690	Basic	2040	1										
	" " "	" "	"	B	26-6	46615	Basic	2035	1										
17	Interlake, Inc.	South Chicago	Ill.	A	25-3	39139	Basic	1680	1								1	1022	:
	" "	" "	"	B	19-1	24454	Foundry	1010	1										

TABLE X (CON'T)

PLANT NUMBER	COMPANY WITH BLAST FURNACE	PLANT NAME	STATE	BLAST FURNACE	HEARTH DIAMETER Ft-In.	WORKING VOLUME OF STACK cubic feet	GRADE PRODUCED	PRODUCTION tons/day	VENTURI SCRUBBER	GAS WASHER	PRECI-PATATOR	ELECTRO-STATIC PRECIP-ATATOR	ORIFICES PLATE SCRUBBER	GAS COOLER	TOWER UNITS	DISINTE-GRATORS	SINTER MACHINES	SINTER GRATE AREA sq.ft.	FIG
18.	Interlake, Inc.	ERIE	Pa.	A	21-0	27550	Basic	1160	1										1
19.	Interlake, Inc.	Toledo	Ohio	A	19-0	25584	Silvery, Basic, Mall. Fdry, Bess Low Phos.	1050	1				1				1	378	2
	" "	"	"	B	22-6	28843		1200											
20	International-Harvester (Wisconsin Steel Div.)	South Chicago	Ill.	1	20-3	23988	Basic	990		4			2			4	1	432	2
	" "	"	"	2	18-9	23117	Basic-Mall.	960											
	" "	"	"	3	23-0	27480	Basic	1150											
21.	Jones + Laughlin Steel	Aliquippa	Pa.	A-1	28-6	43,900	Basic	1900					1	1			1		3
	" " "	"	"	A-2	29-0	56,600	Basic	2500 *					1	1					
	" " "	"	"	A-3	28-6	34,100	Basic	1450					1	1					
	" " "	"	"	A-4	29-0	54,400	Basic	2370					1	1					
	" " "	"	"	A-5	27-3	31,500	Basic	1320					1	1					
22.	Jones + Laughlin Steel	Pittsburgh	Pa.	P-1	22-0	28,600	Basic	1200 *		1									2
	" " "	"	"	P-2	26-6	41,300	Basic	1650 *		1									
	" " "	"	"	P-3	29-0	54,400	Basic	2100 *		1									
	" " "	"	"	P-4	20-6	25,500	Basic	1000 *		1									
	" " "	"	"	P-5	19-3	23,100	Basic	900 *		1									
	" " "	"	"	P-6	26-6	35,400	Basic	1400 *		1									
23	Jones + Laughlin Steel	Cleveland	Ohio	C-1	26-6	41,200	Basic	1780	4		2						1		2
	" " "	"	"	C-2	20-1	21,400	Basic	870											
	" " "	"	"	C-3	29-0	51,500	Basic	2240											

TABLE X (CON'T)

PLANT NUMBER	COMPANY WITH BLAST FURNACE	PLANT NAME	STATE	BLAST FURNACE	HEARTH DIAMETER Ft-In.	WORKING VOLUME OF STACK cubic feet	GRADE PRODUCED	PRODUCTION tons/day	VENTURI SCRUBBER	GAS WASHER	PRECI-PATATOR	ELECTRO-STATIC PRECIP-ATATOR	ORIFICE PLATE SCRUBBER	GAS COOLER	TOWER UNITS	DISINTE-GRATORS	SINTER MACHINES	SINTER GRATE AREA sq.ft.	PIG
24.	Kaiser Steel Corp	Fontana	Calif.	1	27-0	40433	Basic	1740		/							2	1224	/
	" " "	"	"	2	27-0	45900	Basic	2000		/									
	" " "	"	"	3	27-0	40433	Basic	1740		/									
	" " "	"	"	4	29-6	55657	Basic	2440		/									
25	Lone Star Steel Co.	Lone Star	Tex.	1	27-0	44403	Basic	1930		/		2	/				/	550	/
26	McLouth Steel Corp	Trenton	Mich	1	30-0	57238	Basic	2500	/			5							/
	" " "	"	"	2	30-0	57238	Basic	2500	/										
27.	National Steel Corp.	River Rouge	Mich	A	32-0	67,721	Basic	4380		↑		↑							
	" " "	"	"	B	29-0	52,024	Basic	2260											
	" " "	"	"	C	29-0	53,858	Basic	2350											
	" " "	"	"	D	29-6	56,330	BASIC	2460		↓		↓							
28	National Steel Corp.	Weirton	W.Va.	1	27-0	39,887	Basic	1700*		/		2					2	2596	
	" " "	"	"	2	27-0	50,545	Basic	2050*		/		2							
	" " "	"	"	3	25-6	47,030	Basic	1850*		/		2							
	" " "	"	"	4	25-6	47,030	BASIC	2050*		/		3							
29.	Hanna Furnace Corp	Susquehanna	N.Y.	1	16-3	18841	Basic Foundry Malleable Bessemer Silvery	650											
	" " "	"	"	3	15-3	14383		540											
	" " "	"	"	4	19-11	31136		1310											
30.	Republic Steel Corp	Youngstown	Ohio	1	26-3	42700	BASIC	1840	/		/						/	576	
	" " "	"	"	2	25-3	35100	BASIC	1500	/		/								

TABLE X (CON'T)

PLANT NUMBER	COMPANY WITH BLAST FURNACE	PLANT NAME	STATE	BLAST FURNACE	HEARTH DIAMETER Ft-In.	WORKING VOLUME OF STACK cubic feet	GRADE PRODUCED	PRODUCTION tons/day	VENTURI SCRUBBER	GAS WASHER	PRECI-PATATOR	ELECTRO-STATIC PRECIP-ATATOR	ORIFICE PLATE SCRUBBER	GAS COOLER	TOWER UNITS	DISINTE-GRATORS	SINTER MACHINES	SINTER GRATE AREA sq.ft.	FIG
30.	Republic Steel Corp.	Youngstown	Ohio	3	26-3	43,600	BASIC	1850	1		2								
	" " "	"	"	5	19-0	25200	BASIC	1050	1		1								
31.	Republic Steel Corp.	Warren	Ohio	–	28-0	53,100	BASIC	2310		1							1	432	
32.	Republic Steel Corp.	Massillon	Ohio	–	18-6	24,900	BASIC	950		1									1
33.	Republic Steel Corp.	CANTON	Ohio	–	18-4	21,600	BASIC	880		1	1								1
34.	Republic Steel Corp.	Cleveland	Ohio	1	27-0	44,900	BASIC	1950		1	↑						1	419	2
	" " "	"	"	2	17-3	21,000	BASIC	850		1									
	" " "	"	"	3	17-3	21,400	BASIC	865		1	11								
	" " "	"	"	4	27-0	39,500	BASIC	1490		1									
	" " "	"	"	5	28-0	48,200	BASIC	2050		1									
	" " "	"	"	6	28-0	55,300	BASIC	2410		1	↓								
35.	Republic Steel Corp.	Buffalo	N.Y.	1	21-6	27,700	BASIC	1160		1	1								1
	" " "	"	"	2	22-9	33,500	BASIC	1420		1	1								
36.	Republic Steel Corp.	TROY	N.Y.	–	18-3	24,700	Malleable low Phos.	1020		1									1
37.	Republic Steel Corp.	South Chicago	Ill.	–	28-0	54,400	BASIC	2500*		1	2		1				1	432	1
38	Republic Steel Corp.	Gulf Steel	Ala.	1	17-0	20,400	BASIC	820	} 1	1	1						1	569	1
	" " "	"	"	2	26-0	44,500	BASIC	1920		1	1								
39	Republic Steel Corp.	Thomas	Ala.	1	17-0	20,600	Foundry	830		1	1								1
	" " "	"	"	2	17-3	19,700	Foundry	790		1	1								

TABLE X (CON'T)

LANT UMBER	COMPANY WITH BLAST FURNACE	PLANT NAME	STATE	BLAST FURNACE	HEARTH DIAMETER Ft-In.	WORKING VOLUME OF STACK cubic feet	GRADE PRODUCED	PRODUCTION tons/day	VENTURI SCRUBBER	GAS WASHER	PRECIPATATOR	ELECTROSTATIC PRECIPATATOR	ORIFICE PLATE SCRUBBER	GAS COOLER	TOWER UNITS	DISINTEGRATORS	SINTER MACHINES	SINTER GRATE AREA sq.ft.	PIG MACHINES
40.	Sharon Steel Corp.	Farrell	Pa.	2	23-1	30,850	Basic	1300	1										2
	" " "	"	"	3	23-1	31,550	Basic	1330	1										
41.	Shenango, Inc.	Neville	Pa.	A	22-0	29,182	Malleable	1210	1										1
	" "	"	"	B	22-0	29,182	Malleable	1210	1										
42.	Shenango, Inc.	Sharpsville	Pa.	3	20-6	27,485	Malleable	1150		2									1
43.	Tonawanda Iron	Tonawanda	N.Y.	1	16-3	16,440	Malleable Foundry	650		1						1			1
44	U.S. Pipe & Foundry Co.	N. Birmingham	Ala.	5	25-0	44,000	Foundry	1900		1		1							1
45.	U.S. Pipe & Foundry Co.	Birmingham	Ala.	1	15-0	20,886	Foundry	840		1									1
	" " " "	"	"	2	15-4	20,842	Foundry	840		1									
46.	United States Steel Corp.	Clairton	Pa.	1	23-0	30,120	Ferromanganese	1280	1			1							
47.	United States Steel Corp.	Homestead	Pa.	1	23-0	29,597	Basic	1260		1	1						1		1
	" " " "	"	"	3	29-6	51,281	Basic	2230		1	1								
	" " " "	"	"	4	28-0	46,247	Basic	2000		1	1								
	" " " "	"	"	6	23-6	31,558	Basic	1320		1	1								
	" " " "	"	"	7	23-6	31,558	Basic	1320		1									
48	United States Steel Corp.	South Works	Ill.	1	21-6	25,695	Low Phos.	1060	4 ↓			3 ↓			5 ↓	4 ↓	1	1344	1
	" " " "	" "	"	2	23-0	31,702	Low Phos.	1340											
	" " " "	" "	"	3	18-9	23,567	Low Phos.	970											
	" " " "	" "	"	4	25-9	32,114	Low Phos.	1360											
	" " " "	" "	"	E	21-6	25,700	Low Phos.	1060											

TABLE X (CON'T)

PLANT NUMBER	COMPANY WITH BLAST FURNACE	PLANT NAME	STATE	BLAST FURNACE	HEARTH DIAMETER Ft-In.	WORKING VOLUME OF STACK cubic feet	GRADE PRODUCED	PRODUCTION tons/day	VENTURI SCRUBBER	GAS WASHER	PRECI-PATATOR	ELECTRO-STATIC PRECIP-ATATOR	ORIFICE PLATE SCRUBBER	GAS COOLER	TOWER UNITS	DISINTE-GRATORS	SINTER MACHINES	SINTER GRATE AREA sq.ft.	PIG
48	United States Steel Corp.	South Works	Ill.	5	23-0	28,577	Low Phos.	1200											
	" " " "	" "	"	6	22-3	25,758	Low Phos	1060											
	" " " "	" "	"	8	32-0	63,370	Low Phos.	4150											
	" " " "	" "	"	10	25-3	36,232	Low Phos	1540											
	" " " "	" "	"	11	29-0	51004	Low Phos.	2220											
	" " " "	" "	"	12	29.0	51004	Low Phos.	2220											
49.	United States Steel Corp.	Elgar Thomson	Pa.	1	28-10	48,986	Basic Ingot Mold Basic Low Sulfur Low Phos. Malleable	2120									1	576	1
	" " " "	" "	"	2	28-10	48,986		2120											
	" " " "	" "	"	3	26-0	38,837		1670											
	" " " "	" "	"	5	25-0	31,980		1350											
	" " " "	" "	"	6	23.6	32,510		1380											
50.	United States Steel Corp.	Fairfield	Ala	N-1	22-0	31,164	Basic	1310		2		4					4	3104	1
	" " " "	"	"	N-2	22-6	33,235	Basic	1410											
	" " " "	"	"	N-3	21-6	31,865	Ferromanganese	1350											
	" " " "	"	"	N-4	22-0	37,424	Basic	1600											
	" " " "	"	"	N-5	19-0	21,735	Basic	880											
	" " " "	"	"	S-5	25-0	40,829	Basic	1750											
	" " " "	"	"	S-6	25-0	40,995	Basic.	1760											
	" " " "	"	"	S-7	28-9	52,070	Basic	2280											

TABLE X (CON'T)

PLANT NUMBER	COMPANY WITH BLAST FURNACE	PLANT NAME	STATE	BLAST FURNACE	HEARTH DIAMETER Ft-In.	WORKING VOLUME OF STACK cubic feet	GRADE PRODUCED	PRODUCTION tons/day	VENTURI SCRUBBER	GAS WASHER	PRECI-PATATOR	ELECTRO-STATIC PRECIP-ATATOR	ORIFICE PLATE SCRUBBER	GAS COOLER	TOWER UNITS	DISINTE-GRATORS	SINTER MACHINES	SINTER GRATE AREA sq.ft.	PIG
51	United States Steel Corp	Fairless	Pa	1	29-6	55,651	Basic	2912*	3			2			1		2	2787	1
	" " " "	"	"	2	30-10	58,940	Basic	3900	3			2			1				
	" " " "	"	"	3	30-10	58,940	Basic	3900	3			2			1				
52.	United States Steel Corp	Gary	Ind.	1	20-6	24,194	Low Phos.	1000	1		5				14		5	2517	1
	" " " "	"	"	2	20-6	24,194	Low Phos.	1000											
	" " " "	"	"	3	20-6	24,929	Low Phos.	1040											
	" " " "	"	"	4	28-3	47,563	Low Phos	2060											
	" " " "	"	"	5	20-6	27,326	Low Phos	1150											
	" " " "	"	"	6	28-0	47,550	Low Phos.	2060											
	" " " "	"	"	7	28-0	42,106	Low Phos.	1800											
	" " " "	"	"	8	26-6	41,017	Low Phos.	1760											
	" " " "	"	"	9	23-0	28,827	Low Phos.	1200											
	" " " "	"	"	10	27-0	42,680	Low Phos.	1840											
	" " " "	"	"	11	25-0	39,256	Low Phos.	1690											
	" " " "	"	"	12	25-0	39,256	Low Phos.	1690											
53.	United States Steel Corp.	Geneva	Utah	1	26-6	43,666	Basic	1870		1	1	1					2	1224	1
	" " " "	"	"	2	26-6	43,666	Basic	1870		1	1	1							
	" " " "	"	"	3	26-6	43,666	Basic	1870		1	1	1							

TABLE X (CON'T)

PLANT NUMBER	COMPANY WITH BLAST FURNACE	PLANT NAME	STATE	BLAST FURNACE	HEARTH DIAMETER Ft-In.	WORKING VOLUME OF STACK cubic feet	GRADE PRODUCED	PRODUCTION tons/day	VENTURI SCRUBBER	GAS WASHER	PRECI-PATATOR	ELECTRO-STATIC PRECIP-ATATOR	ORIFICE PLATE SCRUBBER	GAS COOLER	TOWER UNITS	DISINTE-GRATORS	SINTER MACHINES	SINTER GRATE AREA sq.ft.
54.	United States Steel Corp.	McKeesport	Pa.	1	24-0	30,613	Blowing Jam	1290		1	5						1	
	" " " "	"	"	2	25-0	34,829	" "	1480		1								
	" " " "	"	"	3	22-5	27,621	" "	1150		1								
	" " " "	"	"	4	22-5	28,329	" "	1190		1								
55.	United States Steel Corp.	Duquesne	Pa	1	20-0	25,409	Low Phos.	1080		2	1	5			5			
	" " " "	"	"	3	23-0	32,713	Low Phos.	1380										
	" " " "	"	"	4	23-0	31,504	Low Phos.	1330										
	" " " "	"	"	6	28-0	49,568	Low Phos.	2150										
56.	United States Steel Corp.	Lorain	Ohio	1	23-0	28,628	Basic	1200	1				4				1	495
	" " " "	"	"	2	23-3	28,973	Basic	1220										
	" " " "	"	"	3	28-6	48,505	Basic	2100										
	" " " "	"	"	4	29-0	49,196	Basic	2130										
	" " " "	"	"	5	23-5	29,589	Basic	1240										
57.	United States Steel Corp.	Cuyahoga	Ohio	A	26-0	42,140	Basic Bess. Fdry Malleable Mach. Pig	1810		1	3							
	" " " "	"	"	D	22-6	28,825		1210		1			1					
53.	United States Steel Corp.	Youngstown	Ohio	2	25-0	37,055	Basic	1590	1		1						1	1344
	" " " "	"	"	3	23-6	34,724	Basic	1480	1		1							
	" " " "	"	"	4	23-0	33,986	Basic	1440			1		1					
	" " " "	"	"	5	25-0	37,356	BASIC	1600	1		1							

TABLE X (CON'T)

PLANT NUMBER	COMPANY WITH BLAST FURNACE	PLANT NAME	STATE	BLAST FURNACE	HEARTH DIAMETER Ft-In.	WORKING VOLUME OF STACK cubic feet	GRADE PRODUCED	PRODUCTION tons/day	VENTURI SCRUBBER	GAS WASHER	PRECI-PATATOR	ELECTRO-STATIC PRECIP-ATATOR	ORIFICE PLATE SCRUBBER	GAS COOLER	TOWER UNITS	DISINTE-GRATORS	SINTER MACHINES	SINTER GRATE AREA sq.ft.	PIG
59	United States Steel Corp.	Duluth	Minn	1	17-7	20779	Basic	840		1	1								1
	" " " "	"	"	2	20-9	25110	Basic	1040		1	2		1						
60	Wheeling-Pittsburgh Steel	Steubenville	Ohio	1	25-0	37,161	Basic	1595					1				1	540	3
	" " "	"	"	2	23-0	29,841	Basic	1260					1						
	" " "	"	"	3	24-0	33,661	Basic	1420					1						
	" " "	"	"	4	21-1	27,639	Basic	1160					1						
	" " "	"	"	5	24-9	40,238	Basic	1720					1						
61.	Wheeling-Pittsburgh Steel	Monessen	Pa.	1	19-0	24,661	Basic	1010					1				1	612	1
	" " "	"	"	2	19-0	25,025	Basic	1030					1						
	" " "	"	"	Jane	28-0	46,596	Basic	2010					1						
62	Woodward Company	Woodward	Ala.	1	17-6	24,033	Foundry	995											1
	" "	"	"	2	17-0	19,011	Malleable	760											
	" "	"	"	3	16-6	18,153	Foundry	710											
	" "	"	"	4	19-0	32,365	Foundry	1370											
63.	Youngstown Sheet + Tube	Campbell	Ohio	1	21-0	27,626	Basic	1200*	1	1							1	528	2
	" " "	"	"	2	21-6	31,226	Basic	1200*	1	1									
	" " "	"	"	3	23-0	37,583	Basic	1800*	1	1									
	" " "	"	"	4	23-0	37,583	Basic	1800*	1	1									
64.	Youngstown Sheet + Tube	Brier Hill	Ohio	1	16-0	19,920	Basic	800	1										1
	" " "	" "	"	2	18-6	25,410	Basic	1050											

TABLE X (CON'T)

PLANT NUMBER	COMPANY WITH BLAST FURNACE	PLANT NAME	STATE	BLAST FURNACE	HEARTH DIAMETER Ft-In.	WORKING VOLUME OF STACK cubic feet	GRADE PRODUCED	PRODUCTION tons/day	VENTURI SCRUBBER	GAS WASHER	PRECI-PATATOR	ELECTRO-STATIC PRECIP-ATATOR	ORIFICE PLATE SCRUBBER	GAS COOLER	TOWER UNITS	DISINTE-GRATORS	SINTER MACHINES	SINTER GRATE AREA sq.ft.
65	Youngstown Sheet + Tube	Indiana Harb.	Ind.	1	26-0	47110	BASIC	2050	1				1				1	1344
	" " "	"	"	2	22-0	32,365	BASIC	1370	1									
	" " "	"	"	3	28-0	52,000	BASIC	2270	1									
	" " "	"	"	Ellow	32-0	63,870	BASIC	4000*	1									

* Indicates production data taken from published sources

40518
33 = 12

Based upon the data available from 87 blast furnaces with total capacities of 88,327 tons of iron per day, the following figures were obtained: *

Washer Water Volume = 3,204 gals.per ton of iron

Dry Flue Dust Produced = 146 lbs. per ton of iron

Wet Dust Produced = 58.6 lbs. per ton of iron

Cooling water use is best estimated from the U.S.G.S. data "Water Use in the Steel Industry" (1967) from which the average is 19,100 gals. per ton of pig iron. The same source indicates additional uses for boiler feed, sanitary and service, and "other" at 2,920 gals. per ton of pig iron. The total use is thus indicated to be 25,224 gals. per ton of pig iron. This figure is much higher than has been preciously indicated by most sources. The figure most often quoted for total water use in the industry is 40,000 gallons per ton of finished steel (Nebolsine)** with 25% of this used in the blast furnace department. Production data for 1968 are as follow, in the year in which the industry used 6504 billion gallons of water (1968 census of Manufacturers), with corresponding water use rates:

Finished Steel (shipments): 91.856 million tons = 70,806 gals./finished ton

Raw Steel Production: 131.462 million tons : 49,474 gals/ingot ton

Pig Iron Production: 89.333 million tons

It is apparent from these data that the water use statistics used in the past have been confused by intake or net use data being used interchangably with gross use data. Later progress reports will investigate this factor in detail.

The Raw Waste Loads of various constituents are estimated below on the basis of the available data from 13 plants, detailed in the following table, in addition to the previously given data.

---

* Ohio River Valley Water Sanitation Commission, "Dust Recovery Practices at Blast Furnaces", January, 1958.

** E. Fred Gurnham Principles of Industrial Waste Treatment, John Wiley & Sons, Inc.

Flow, gal. ton	3204
Suspended Solids, #/ton	58.6
Phenol, #/ton	0.021
River Water Quench	0.001
Cyanide, #/ton	0.078
Fluorides, #/ton	0.046
Ammonia, #/ton	0.545
Alkalinity ($CaCO_3$), #/ton	5.17

The Present Practice Waste Load probably corresponds to the use of plain sedimentation with 95% removal of suspended solids, no signifigant removal of other contaminants, and widespread waste water quenching of coke.

Flow, gal./ton	3204
Suspended Solids, #/ton	2.93
Phenol, #/ton	0.021
Cyanide, #/ton	0.078
Fluorides, #/ton	0.046
Ammonia, #/ton	0.545
Alkalinity, #/ton	5.17

The Base Level of Treatment may be taken as chemical coagulation, alkaline chlorination, and no use of waste water for coke quenching.

Flow, gal./ton	3204
Suspended Solids, #/ton	0.254
Phenol, #/ton	0.001
Cyanide, #/ton	0.0002
Fluorides, #/ton	0.046
Ammonia, #/ton	0.036
Alkalinity, #/ton	5.17

TABLE XI

BLAST FURNACE WASTE WATER DATA

PLANT	CAPACITY	Flow		CYANIDE			Phenols			Fluorides		Ammonia			Alkalinity		pH	Remarks
	Tons/day	gpm	gal/ton	ppm	#/day	#/ton	ppm	#/day	#/ton	ppm	#/ton	ppm	#/day	#/ton	ppm	#/ton		
1	-	-	4730	1.28	-	0.050	0.72	-	0.028	-	-	-	-	-	290	11.4	7.6	Quench with still wastes
2a	-	-	3250	0.79	-	0.021	0.03	-	0.0008	-	-	-	-	-	141	3.82	8.0	Quench with river water
2b	-	-	2280	0.66	-	0.013	0.07	-	0.0013	-	-	-	-	-	147	2.79	8.5	Quench with river water
3	-	-	3300	-	-	-	-	-	-	-	-	-	-	-	-	-	8.3	Quench with still wastes
4	-	-	-	-	-	-	0.706	-	0.0243	1.01	0.0331	-	-	-	-	-	-	"
5	-	-	-	-	-	-	0.411	-	0.0194	1.27	0.0632	-	-	-	-	-	-	"
6	-	-	-	-	-	-	0.321	-	0.0231	1.14	0.109	-	-	-	-	-	-	"
7	-	-	-	-	-	-	3.822	-	0.0819	0.37	0.00807	-	-	-	-	-	-	"
8	-	-	-	-	-	-	-	-	-	0.75	0.0154	-	-	-	-	-	-	-
VI	2710	-	2657	3	-	0.066	0.100	-	0.0022	-	-	-	-	-	-	-	-	-
Samples	-	-	(3204)	1.12	-	0.030	0.210	-	0.0056	-	-	24.4	-	0.65	100	2.67	-	-
XIV	2500	3700	2131	0.01	-	0.0002	0.134	-	0.002	-	-	2.0	-	0.036	-	-	8.2	Alkaline Chlorination & Coagulation 14.3 ppm suspended solids = 0.254 #/ton
III	7650		-	-	2181	0.285	-	71.6	0.009	-	-	-	-	-	-	-	-	-
XIV	2500	3700	2131	-	195	0.078	-	100	0.040	-	-	-	1100	0.44	-	-	7.4	-
XV	6000	600	144	0.73	-	0.0009	14.6	-	0.0175	-	-	186	-	0.223	396	0.475	8.1	Blowdown from recycle 64 ppm suspended solids = 0.320 #/ton ($2,000,000)
Sinter Plant VI	3300	540																18.8 # s.s. per ton sinter

(1) Not included in Raw Waste Load Data

The Best Practicable Treatment may be taken as recirculation with a blowdown of 5% of the recirculation rate, treated by alkaline chlorination, and no use of waste water for quenching.

Flow, gal./ton	160
Suspended Solids, #/ton	0.013
Phenol, #/ton	neg.
Cyanide, #/ton	neg.
Fluorides, #/ton	0.002
Ammonia, #/ton	0.002
Alkalinity, #/ton	0.259

The Best Available Treatment is recirculation with no blowdown, blowdown used in slag quenching, blowdown disposed on ore piles, or blowdown to co-treatment in municipal plants. Discharge of pollutants would thus be zero.

Summarizing the waste load data for blast furnaces:

	SRWL	PRWL	BLT	BPT	BAT
Flow, gal./ton	3204	3204	3204	160	0
Suspended Solids, #/ton	58.6	2.93	0.254	0.013	0
Phenol, #/ton	0.021	0.021	-	-	-
River Water Quench	0.001	-	0.001	neg.	-
Cyanide, #/ton	0.078	0.078	0.0002	neg.	0
Fluorides, #/ton	0.046	0.046	0.046	0.002	0
Ammonia, #/ton	0.545	0.545	0.036	0.002	0
Alkalinity, #/ton	5.17	5.17	5.17	0.259	0

The reported cost of a recirculation system involving no chemical treatment for 4 blast furnaces producing 6,000 tons of pig iron per day was $2,000,000. The cost of a recirculating system for a 2,500 ton/day blast furnace has been estimated at $1,000,000. A cost of about $350 per daily ton of iron, or about $1 per annual ton seems to be a fair average figure. The cost of chemical treatment alone is probably about the same. Cost of water use in the steel industry is about $21 per million gallons (OWRR-value of water in industry), when depreciation is not included. Per ton of pig iron then, $3204 \times 10^{-6} \times \$21 = \$0.067$ per ton of pig iron.

Plain Sedimentation:

$$\frac{\$1.25}{\text{ingot ton}} \times \frac{\text{ingot ton}}{0.67 \text{ tons iron}} = \$1.87/\text{ton iron}$$

$$\text{annualized @ 8\%, 10 yrs.} = \frac{1.87}{8.5136} = \$0.220/\text{ton iron}$$

$$= \$0.287/\text{ton iron (1966)}$$

$$= \$0.287 \times \frac{1690}{1000} = \$0.485/\text{ton iron}$$

Coagulation/Sedimentation:

$$\frac{\$1.38}{\text{ingot ton}} \times \frac{\text{ingot ton}}{0.67 \text{ tons iron}} = \$2.06/\text{ton iron}$$

$$\text{annualized @ 8\%, 10 years} = \frac{2.06}{8.5136} = \$0.242/\text{ton iron}$$

$$= \$0.309/\text{ton iron (1966)}$$

$$= \$0.309 \times \frac{1690}{1000} = \$0.522/\text{ton iron}$$

Recirculation and Coagulation/Sedimentation:

$$\frac{\$1.80}{0.67} = \$2.69/\text{ton iron} \quad 8.5136 = \$0.316/\text{ton iron}$$

$$= 0.383 \times 1.69 = \$0.6473/\text{ton iron}$$

Specific Best Practile Plants:

1. Recycle
    - a. Youngstown S & T Campbell
    - b. U. S. Steel-South Chicago
    - c. U. S. Steel-Fairfield
    - d. Fontanna

    e. Interlake

2. Chemical Coagulation

    a. Republic-South Chicago

3. Alkaline Chlorination

    a. Wisconsin Steel

    b. Republic-South Chicago

SINTER PLANTS

Fine ores must be converted to a lump form by some process of agglomeration before they can be effectively used in the blast furnace. Sintering is the principal method used to reclaim flue dust and mill scale for recharging to the blast furnace and to agglomerate fine ores as a part of the blast furnace shop. In sintering, the fine iron-bearing material is mixed with a fuel and burned on a grate under forced draft to a clinker.

Dust produced in the sintering plant is often recovered using wet scrubbers as an air pollution abatement measure. Wet scrubbers are coming into increasing use due to the explosion hazards with precipitators.

The dust from a sintering plant amounts to about 20 lbs. of solids per ton of sinter produced. The Interlake data seems to support this generally accepted value. Sinter production averages about 3.35 tons per day/ft.^{2} of grate area. The "average" sinter plant is thus estimated to produce 4,113 tons per day from a grate area of 1,228 sq. ft. on 2 machines. A venturi scrubber using 1,000gpm of wash water would thus produce 350 gals. of waste water per ton of sinter containing 6,858 ppm suspended solids. Present Practice Waste Loads result from plain sedimentation and at 95% removal amount to above 1.0 lbs. per ton of sinter. Chemical coagulation as the Base Level of Treatment would reduce the thickener effluent to 15 ppm, corresponding to 0.044 lbs. per ton. The Best Practicable Treatment at recirculation with 5% blowdown would yield a load of 0.0022 lbs. per ton. The Best Available Treatment probably corresponds to zero discharge since the sinter plant blowdown can usually be disposed of with that from a blast furnace system. The higher cost associated with blast furnace recirculating systems, i.e., $1,000,000 per installation, $243 daily ton is probably the approximate cost involved, i.e., about $0.67 per annual ton. An operating cost of $0.17 per ton is indicated.

Assuming that the 6 single-machine plants of unknown size are of the average size of the machines in the other 33 plants, the total grate are of 44,202 sq. ft. indicates a daily capacity of 148,077 tons, or 54 million tons annually.

FERROMANGANESE BLAST FURNACES

Ferromanganese production in blast furnaces has steadily decreased; less than 50% was produced thus in 1970. The operation differs from the manufacture of pig iron in that manganese ores or mixtures of manganese and iron ores are used and the furnace temperature is higher. Oxygen enrichments of the blast as high as 30% are now used in such furnaces. The suspended solids are much finer than from basic iron furnaces and the production of cyanide is much greater.

The suspended solids from ferromanganese blast furnaces are light in color and amount to about 300 lbs. per ton of metal produced. (Taff Lenter, May, 1961, Review for U. S. House of Representatives). Cyanide production is about 20 times that from a iron-making blast furnace (A.I.S.I.).

BLAST FURNACE AND SINTER PLANT TREATMENT COSTS

The costs of wastewater treatment here are estimated from the 1967 Steel Industry Profile.

Sinter plant production in 1966 was 54.3 million tons and pig iron production was 91.5 million tons. The total water use, using the present study figures, would have been:

$$\frac{(3204 \times 91.5) + (54.3 \times 350)}{91.5} = 3412 \text{ gal./ton pig iron}$$

This is essentially the same as the Profile estimate of water use, so that the costs per unit of water treated may be used.

Direct costs (labor, supervision, maintenance, chemicals); 1966 $:

Plain sedimentation: $0.138/1,000 gal. x 3.412 = $0.471/ton iron

Coagulation - sedimentation: $0.214/1,000 gal. x 3.412 = $0.730/ton iron

Difference in operating costs in 1972 $@ 3.5% per year:

$(\$0.730 - \$0.471) \times (1.035)^6 = \$0.319$/ton iron

Operating costs in 1972 $:

Plain sedimentation: $\$0.471 \times (1.035)^6 =$ $0.579/ton iron

Coagulation - sedimentation: $\$0.731 \times (1.035)^6 =$ $0.898/ton iron

The capital costs of various wastewater treatment methods for blast furnaces and sinter plants together are:

Treatment Method	$1966/ingot ton/yr.	$1972/ton of iron/yr.
Plain Sedimentation	1.25	2.29
Coagulation-Sedimentation	1.38	2.53
Recirculation and:		
Plain Sedimentation	1.50	2.75
Coagulation-Sedimentation	1.80	3.30

Operating costs per year as a percentage of capital cost:

Plain Sedimentation	25.3%
Coagulation-Sedimentation	35.5%
Recirculation and:	
Plain Sedimentation	21.1%
Coagulation-Sedimentation	27.2%

Scale factors for capital costs of treating blast furnaces and sinter plants alone:

$\left(\frac{350}{3412}\right)^{0.6}$ = 0.255 x combined plant for sinter plant/ton sinter

$350 \times \left(\frac{54.3}{91.5}\right)$ = 208 gals. in sinter plant/ton iron

$\left(\frac{3204}{3412}\right)^{0.6}$ = 0.963 x combined plant for blast furnace/ton iron

Treatment Method	Blast Furnace ton iron/yr.	Sinter Plant ton Sinter/yr.
Plain Sedimentation	$2.21	$ 0.58
Coagulation-Sedimentation	2.44	0.65
Recirculation and:		
Plain Sedimentation	2.65	0.70
Coagulation-Sedimentation	3.18	0.84

Operating costs for these treatments:

Treatment Method	Blast Furnace/ton iron	Sinter Plant/ton sinter
Plain Sedimentation	$0.56	$ 0.15
Coagulation-Sedimentation	0.87	0.23
Recirculation and:		
Plain Sedimentation	0.56	0.15
Coagulation-Sedimentation	0.87	0.23

These costs are applicable only to facilities initially built as described. Additions to present plants probably cost 50-100% more than the differences indicated for blast furnaces and as much as for the original facility for sinter plants.

STEELMAKING OPERATIONS

The principal steelmaking methods in use today are the Basic Oxygen Furnace (BOF or BOP), the Open Hearth Furnace, and the Electric Arc Furnace. Little or no steel is now produced in Bessemer Convertors. The Q-BOP is the newest of the steelmaking processes, developed in Germany and licensed to U. S. Steel Corporation in this country. The Q-BOP may well become the steelmaking process of the future. (see p 129)

The steelmaking processes all basically refine the product of the blast furnace blended with scrap or scrap alone, and alloying elements to required analyses for particular purposes. Steel is any alloy of iron containing less than 1.8% carbon. The steelmaking process consists essentially of oxidizing constituents, particularly carbon, down to specified low levels, and then adding various elements to required amounts as determined by the grade of steel to be produced.

The basic raw materials for steelmaking are hot metal or pig iron, steel scrap, limestone, burned lime, dolomite, fluorspar, iron ores, iron-bearing materials such as pellets or mill scale, and various addition agents which may be the metallic elements or ferrous alloys of such elements as manganese, silicon, chromium, vanadium, nickel, etc.

The steelmaking processes produce fume, smoke, and waste gases as the unwanted impurities are burned off and the process vaporizes or entrains a portion of the molten steel into the off-gases. Other impurities combine with the slag which floats on the surface of the bath and is separately withdrawn. Wastewater results from the steelmaking processes when wet dust collection systems are used on the furnaces and in the slag handling operations.

Dry collection methods require that the gas temperature be reduced to about 500°F or less. This may be accomplished by the use of waste heat boilers, evaporation chambers, or spray cooling (spark chambers). Waste heat boilers and evaporation chambers do not result in wastewater effluents. Spray cooling or quenching and/or the use of wet washers result in wastewaters containing all or a portion of the particulates in the gas.

The total raw steel production in the United States by type of furnace is shown in Table XII and graphically illustrated in Figure 17 for the past 15 years. Both Electric furnace and Basic Oxygen furnace production have been steadily increasing as open hearth production has decreased from a high of 90.2% of the total steel production to 29.5% in 1971. For the same period carbon grade steel has represented about 90% of the total production as shown below:

	Percent of Total Production		
Year	Carbon	Alloy	Stainless
1971	88.8	10.1	1.1
1970	89.3	9.7	1.0
1969	88.4	10.5	1.1
1968	88.4	10.5	1.1
1967	89.0	9.9	1.1
1966	88.5	10.2	1.3
1965	88.8	10.1	1.1
1964	90.1	8.8	1.1
1963	90.3	8.6	1.1

Year	Percent of Total Production		
	Carbon	Alloy	Stainless
1962	90.7	8.2	1.1
1961	91.1	7.7	1.2
1960	91.5	7.5	1.0
1959	90.5	8.3	1.2
1958	92.2	6.7	1.1
1957	92.1	7.0	0.9

Source: American Iron and Steel Institute 1971 Annual Statistical Report

Figure/8 summarizes the production of the various grades of steel by furnace type in 1971.

Open Hearth Furnaces

Although declining in recent years, 30 percent of the steel produced in the United States is still made in open hearth furnaces. Open hearth furnaces, while similar in design, may vary widely in tonnage capacity. The furnaces found in this country range in capacity from 10 to 600 tons per heat.

The main body of an open hearth furnace is the hearth itself. Hearths are constructed of refractory brick supported by I beams. The steelmaking ingredients (iron, scrap, limestone, alloys, etc.) are charged into the front of the furnace through movable doors. Flame to "cook" the steel is supplied by liquid or gaseous fuel which is ignited by hot air. Continuous hot air flow is maintained by use of a system of regenerative refractory chambers which are located at either side of the furnace.

As hot air flows horizontally across the hearth, it serves the dual purpose of fuel ignition and heating of the opposite regenerative chamber. Flow is periodically reversed to maintain

TABLE XII

Raw Steel Production by Type of Furnace

(thousands of net tons)

Year	Open Hearth		B.O.F.		Electric		Bessemer		Total Production
	Production	% of Total	Production	% of Total	Production	% of Total	Production	% of Total	
1971	35,559	29.5	63,943	53.1	20,941	17.4	---	---	120,443
1970	48,022	36.5	63,330	48.2	20,162	15.3	---	---	131,514
1969	60,894	43.1	60,236	42.6	20,132	14.3	---	---	141,262
1968	65,836	50.1	48,812	37.1	16,814	12.8	Included in Open Hearth		131,462
1967	70,690	55.6	41,434	32.6	15,089	11.9	Included in Open Hearth		127,213
1966	85,025	63.4	33,928	25.3	14,870	11.1	278	0.2	134,101
1965	94,193	71.7	22,879	17.4	13,804	10.5	586	0.4	131,462
1964	98,098	77.2	15,442	12.2	12,678	10.0	858	0.7	127,076
1963	88,834	81.3	8,544	7.8	10,920	10.0	963	0.9	109,261
1962	82,957	84.4	5,553	5.6	9,013	9.2	805	0.8	98,328
1961	84,368	86.1	3,967	4.0	8,664	8.8	881	0.9	98,014
1960	86,368	87.0	3,346	3.4	8,379	8.4	1,189	1.2	99,262
1959	81,669	87.4	1,864	2.0	8,533	9.1	1,380	1.5	93,446
1958	75,880	89.0	1,323	1.6	6,656	7.8	1,396	1.6	85,255
1957	101,658	90.2	611	0.5	7,971	7.1	2,475	2.2	112,715

FIGURE 17

RAW STEEL PRODUCTION BY TYPE OF FURNACE

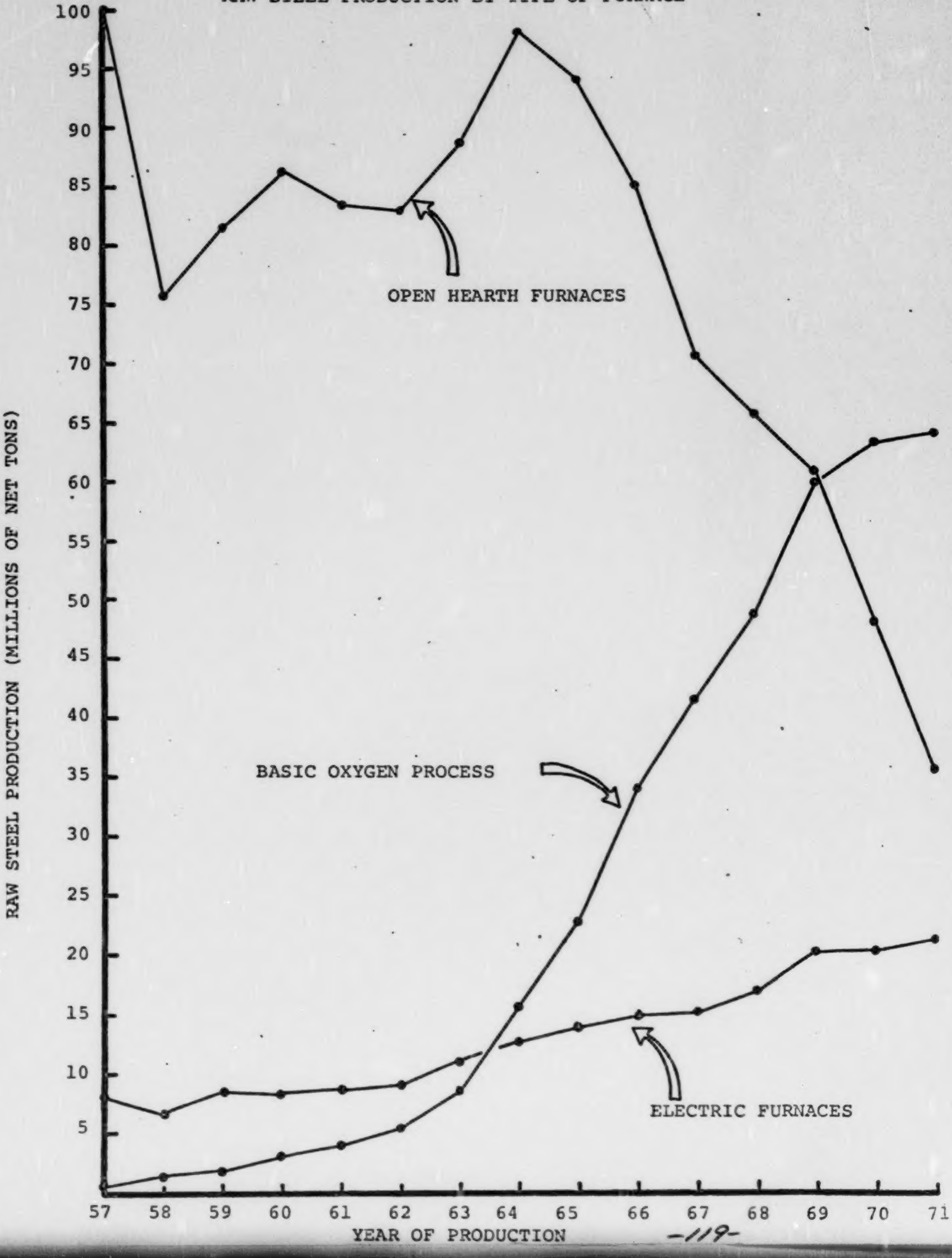
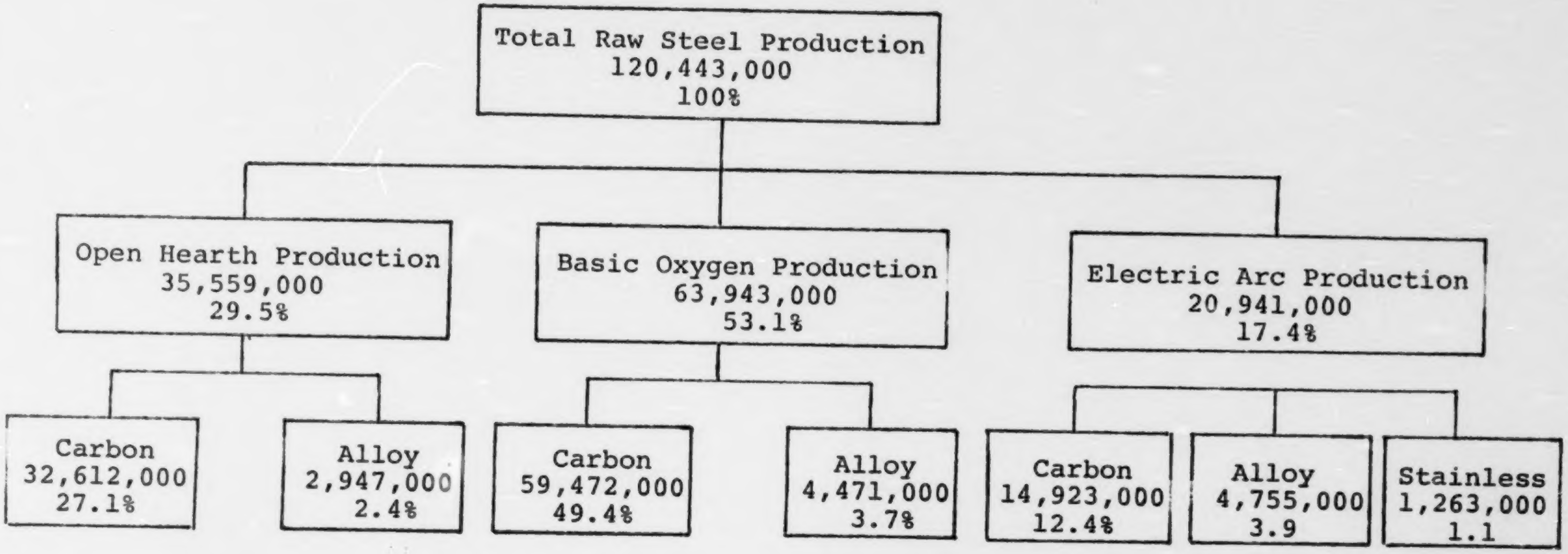


Figure 18

Raw Steel Production by Type of Furnace and Grade - 1971



an even hot air flow. The molten steel is tapped from the furnace when the desired analyses specifications have been obtained. In the standard furnace, this occurs 10-12 hours after the first charge. Many furnaces use oxygen lances which are used on the first charge and create a much more intense heat and reduce charge-to-tap time. These lances (usually 2 or 3) are located in the furnace roof directly over the hearth. The tap-to-tap time for the oxygen-lanced open hearth probably averages about 8 hours, with about 12 hours being the average when oxygen is not used.

The open hearth furnace allows the operator to, in effect, "cook" the steel to required specifications. The nature of the furnace permits him to continually sample the batch content and make necessary additions. The major drawback of the process is the long time required to produce a "heat". Many basic oxygen furnaces can produce eight times the steel of a comparable open hearth over the same period of production time.

With the use of oxygen lances, the duration of a heat is about 5 to 8 hours. The use of oxygen greatly increases the rate of fume generation

oxygen. The rate of fume generation with oxygen-lancing has been variously reported at from 9.3 to 30 lbs. per ingot ton, the highest figure being reported for the highest known oxygen rate at the Steel Company of Canada, Ltd., Hamilton, Ontario. Fume generation rates of about 25 lbs. per ton with oxygen-lancing and about 8 lbs. per ton without lancing probably best represents current practice. These to the standard raw waste load when Venturi scrubbers are used remove the fumes from the vented gases.

The use of precipitators to clean the gas may or may not result in a waste water discharge. When an evaporation chamber is used to cool the gas, no wastewater discharge results, since all of the water is evaporated into the gas. When a spark chamber (spray tower) is used to cool the gas, the excess water is discharged as wastewater. The solids may be collected from the precipitators in a completely dry form or as a thick slurry after mixing with water in a pug mill. In neither case should a wastewater stream result from this operation. In some cases, however, the collected solids have been mixed with the water from the spark chamber and sent to a clarifier. Such a practice results in a raw waste load equal to that of the Venturi scrubbers.

Since the introduction in the United States of the more productive basic oxygen process, open hearth production has declined from a peak of 103 million tons in 1956 to 35 million tons in 1971. Of the two basic grades of steel produced by the open hearth process, carbon grade steel is by far the most prominent. During the past fifteen years, carbon grade steel averaged 92% of the total open hearth production. As shown below, alloy steel production in the open hearth has increased from about 6% in 1957 to 8-9% during 1972-73.

Open Hearth Production by Grade of Steel

Year	Carbon (1,000 tons)	% of Open Hearth Production	Alloy (1,000 tons)	% of Open Hearth Production
1971	32,612	91.7	2,947	8.3
1970	44,361	92.4	3,661	7.6
1969	55,530	91.2	5,364	8.8
1968	59,572	90.5	6,264	9.5
1967	64,265	90.9	6,425	9.1
1966	77,395	91.0	7,630	9.0
1965	85,861	91.2	8,332	8.8
1964	90,763	92.5	7,335	7.5
1963	82,621	93.0	6,213	7.0
1962	77,569	93.5	5,388	6.5
1961	79,525	94.1	4,977	5.9
1960	81,171	94.0	5,197	6.0
1959	76,436	93.6	5,233	6.4
1958	71,869	94.7	4,011	5.3
1957	95,742	94.2	5,916	5.8

Source: American Iron and Steel Institute 1971 Annual Statistical Report

Basic Oxygen Furnaces

BOF steel production first equaled that from open hearths in 1969. Now the BOP is clearly the major steelmaking process.

Vessels for the basic oxygen process are generally vertical cylinders surmounted on a truncated cone. High-purity oxygen is supplied at high pressure through a water-cooled tube mounted above the center of the vessel. Scrap and molten iron are charged to the vessel and a flux is added. The oxygen lance is lowered and oxygen is admitted. A violent reaction occurs immediately and the resultant turbulence brings the molten metal and the hot gases into intimate contact, causing the impurities to burn off quickly. An oxygen blow of 18 to 22 minutes is normally sufficient to refine the metal. Alloy additions are made and the steel is ready to be tapped.

A basic oxygen furnace can produce 200 to 300 or more tons of steel per hour and allows very close control of steel quality. A major advantage of the process is the ability to handle a wide range of raw materials. Scrap may be light or heavy, and the oxide charge may be iron ore, sinter, pellets, or mill scale.

As with the open hearth, the water pollution potential from the BOF is in the water used to cool and/or clean the off-gases as an air pollution abatement measure. The particulate matter generated has been reported at 40 to 46 lbs. per ingot ton, a much narrower range than in the case of open hearths. An average value of 41 lbs. per ingot ton probably best defines the Standard Raw Waste Load. As previously described for the case of the open hearth, such a load results when Venturi scrubbers are used, or when the solids collected from precipitators are mixed with water from spray cooling. The use of an evaporation chamber and separate solids collection from precipitators should produce no wastewater effluents.

The annual production of steel in the United States by the basic oxygen process has increased from about 600,000 tons in 1957 to 64 million tons in 1971. It is anticipated that basic oxygen production will continue to increase at the expense of open hearth production. During the past seven years, alloy steel production in the basic oxygen process has steadily increased from 1 million tons in 1965 to over 4 million tons in 1971.

Like the open hearth, however, the principal grade of steel produced in the basic oxygen furnace is carbon, accounting for about 93% of total production as shown below.

Basic Oxygen Process Production by Grade of Steel

Year	Carbon (1,000 tons)	% of B.O.P. Production	Alloy (1,000 tons)	% of B.O.P. Production
1971	59,472	93.0	4,471	7.0
1970	58,889	93.0	4,441	7.0
1969	55,927	92.8	4,309	7.2
1968	45,706	93.6	3,106	6.4
1967	38,811	93.7	2,623	6.3
1966	31,892	94.0	2,036	6.0
1965	21,787	95.2	1,092	4.8
1964	15,045	97.4	397	2.6
1963	8,484	99.3	60	0.7
1962	5,503	99.1	50	0.9
1961	3,961	99.8	6	0.2
1960	3,344	99.9	2	0.1
1959	1,864	100.0	--	--
1958	1,323	100.0	--	--
1957	611	100.0	--	--

Source: American Iron and Steel Institute 1971 Annual Statistical Report

Electric-Arc Furnaces

The electric-arc furnace is uniquely adapted to the production of high-quality steels, however, most of the production is carbon steel. Practically all stainless steel is produced in electric-arc furnaces. Electric furnaces range up to 30 feet in diameter and produce from 2 to 400 tons per cycle in 1.5 to 5 hours.

The cycle in electric furnace steelmaking consists of the meltdown, the molten-metal period, the boil, the refining period, and the pour. The required heat is generated by an electric arc passing from the electrodes to the charge in the furnace. The refining process is similar to that of the open-hearth, but more precise control is possible in the electric furnace. Use of oxygen in the electric furnace has been common practice for many years.

Electric-arc furnaces are to be found in almost every integrated steel mill. Many mills operate only electric furnaces, using scrap as the raw material. In most "cold shops" the electric-arc furnace is the sole steelmaking process.

Wastewater is generated from electric-arc furnaces when excess water is used to cool the gas or when Venturi scrubbers are used. Baghouses are predominantly used with electric furnaces and the wastewater potentials are the same as with precipitators. Particulate generation has been reported at from 10 to 15 lbs. per ingot ton, the average being 11.7 lbs. per ingot ton. This would be the Standard Raw Waste Load with Venturi scrubbers or when solids collected in precipitators or baghouses were mixed with spray cooling water. Particulate emissions are reportedly about doubled when dirty, sub-quality scrap is used.

The annual production of steel in the electric-arc furnace has increased from about 8 million tons in 1957 to some 21 million tons in 1971. Although electric-arc furnaces have been small in heat capacity as compared to open hearth or basic oxygen furnaces, a trend towards larger furnaces has recently developed. As an example, Northwestern Steel and Wire Company has recently installed a new 400 ton per heat electric furnace at its Sterling, Illinois plant. It may also be noted that the new electric-arc furnaces are not only increasing present plant capacity, but are also replacing the fading open hearth process. It is not expected that the B.O.P. will compete with the electric-arc furnace since the B.O.P. is essentially a hot-metal process and the electric-arc is a scrap-based process. In addition the electric-arc furnace now accounts for all the stainless steel production. Electric-arc furnaces are the principal steelmaking process utilized by the so-called mini steel plants which have been built since World War II. Carbon, alloy, and stainless production in electric-arc furnaces for the past 15 years is shown on the following page.

TABLE XIII

Electric-Arc Furnace Production by Grade of Steel

Year	Carbon (1,000 tons)	% of Elec. Furn. Production	Alloy (1,000 tons)	% of Elec. Furn. Production	Stainless (1,000 tons)	% of Electric Arc Production
1971	14,923	71.3	4,755	22.7	1,263	6.0
1970	14,161	70.2	4,722	23.4	1,279	6.3
1969	13,375	66.4	5,188	25.8	1,569	7.8
1968	10,991	65.4	4,391	26.1	1,432	8.5
1967	10,114	67.0	3,524	23.4	1,451	9.6
1966	9,167	61.6	4,052	27.2	1,651	11.1
1965	8,417	61.0	3,894	28.2	1,493	10.8
1964	7,776	61.3	3,459	27.3	1,443	11.4
1963	6,646	60.9	3,070	28.1	1,204	11.0
1962	5,283	58.6	2,645	29.3	1,085	12.0
1961	4,971	57.4	2,556	29.5	1,137	13.1
1960	5,158	61.6	2,217	26.5	1,004	12.0
1959	4,859	56.9	2,543	29.8	1,131	13.3
1958	4,003	60.1	1,757	26.4	896	13.5
1957	4,975	62.4	1,949	24.5	1,047	13.1

Since 1966, the growth rate of electric furnace steel production has been on a 10% annual increase curve, and a predicted 45% of United States raw steel capacity is anticipated for electric furnaces by 1980.

Q - Basic Oxygen Process

Recently, the United States Steel Corporation announced the development of a high volume adaptation of the Q-BOP process invented by Maxhutte of West Germany. European experience with this process is limited and has involved relatively small units of 40 ton capacity. Through U. S. Steel research efforts, the process has been improved so that it can produce a high volume of steel and utilize greater amounts of scrap. The principle difference between the Q-BOP and the BOP lies in the oxygen system. Instead of injecting oxygen at the top of the vessel, oxygen is enveloped in a protective fluid stream and injected into a Q-BOP furnace at the bottom, through gas-cooled tuyeres. It has been estimated that the Q-BOP can be built for half the cost of a conventional BOP and is cheaper to operate. As a result, U. S. Steel has begun construction of two 200-ton units at its Birmingham plant and is converting three-200 ton BOP at Gary. Particulate generation would be expected to be about the same as with the conventional basic oxygen furnace, but no data are available.

Vacuum Degassing

In the Vacuum Degassing Process, steel is further refined by subjecting the steel in the ladle to a high vacuum in an enclosed refractory lined chamber. The oxygen and carbon and some steel in the bath are oxidized further and are emitted as CO gas and iron oxide fumes. A four or five stage steam jet ejector with barometric condensers are used to draw the vacuum.

A means of providing heat is furnished in the process by electric carbon heating rods to replace the heat lost in the process or in some cases to raise the temperature of the steel bath. Alloys are generally added during this process and the cycle time is approximately 25 to 30 minutes. The waste products from Vacuum Degassing process are condensed steam and waste with iron oxide fumes and CO gases entrained in discharge effluent.

Teeming (Pouring)

If the steel is brought to the teeming area, a string of ingot cars with cast iron ingot molds are stationed in an aisle. The mill crane holds the steel ladle and passes over each ingot mold filling it with molten steel. After finishing pouring the steel, the mill crane dumps remaining slag and returns for another heat of steel. The ingots are allowed to cool (so a hard skin forms) and then are taken to a mold stripper area where the hot ingot is removed from the ingot mold. The ingots are then transported to soaking pits for reheating and then rolling in the rolling mills. The ingot molds are transported back to a mold preparation area where they are cleaned and prepared for the next heat cycle. During the teeming operation, some materials are added to the steel such as aluminum or lead shot. The aluminum acts as an oxidizing agent and lead is used for making leaded steels.

Anti-sticking treatments are used on the inside of the ingot molds to prevent stacking between hot steel and molds. One method is a process where oil is sprayed on the inside of the mold, another method is a powder which is dusted inside the mold. The molds are usually water sprayed to cool them faster so as to obtain minimum turn around time.

The waste products from the teeming and mold cycle are generally contaminants that have been spilled, etc., and reach sewers via groundwater.

Continuous Casting

If the steel is not put through the teeming operation the steel ladle is transported to the Continuous Casting area. In the Continuous Casting process billets, blooms and slabs are cast directly from the hot steel, thus eliminating ingots, soaking pits, mold preparation and stripping facilities. In this process, the steel ladle directs the hot steel into water cooled open ended copper molds. As the steel begins to pass through the copper mold, the outer skin cools and forms a hard steel shell with a liquid center. As the steel slab, bloom or billet emerges from the mold, it enters a spray area. Water is sprayed on the steel, thus cooling it further. The steel slab, bloom or billet then passes a cutoff point where it is cut to a definite length, transported on run-out tables to a stacker and storage area.

The mold cooling and machine cooling systems are usually closed systems and thus water picks up only heat. In the spray zone area, water is sprayed on the steel and the effluent is discharged. The waste products from this process are steel scale and possibly oil from the machinery.

The remaining processes involved with steelmaking operations are the slag handling and oxygen generation plants.

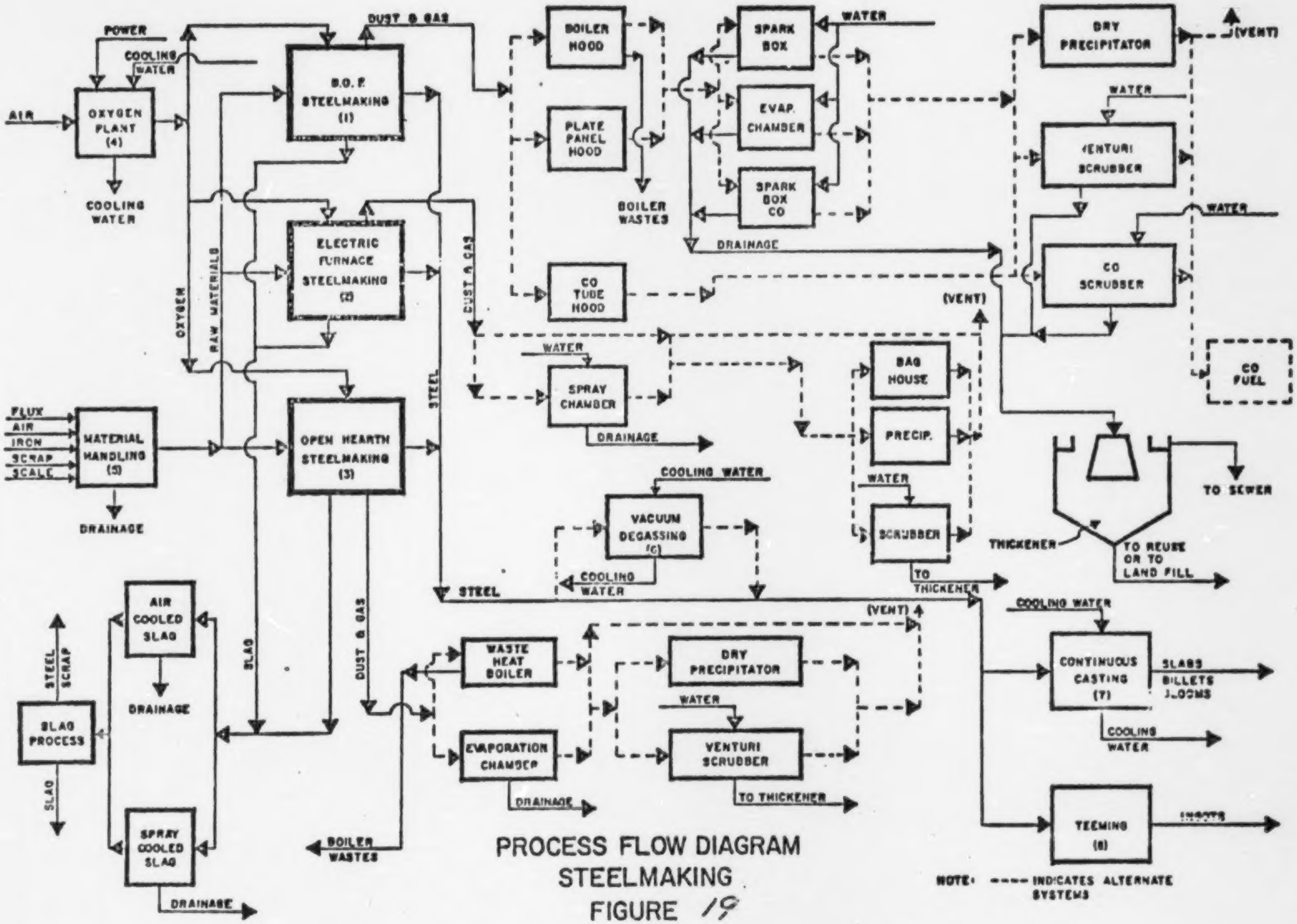
Slag Handling

For all of the three steelmaking processes, slag is always generated. The slag is generally deposited into ladles from the furnaces. These ladles are transported to a slag dump where the slag is allowed to air cool or is sprayed with water. The slag is then transported to a slag processing plant where iron is relaimed and slag crushed into a saleable product. The waste products from this process are generally airborne dust and become waterborne when wet dust collecting systems are added. When Open Hearth slag is wetted, hydrogen sulfide will be emitted due to sulfur content of slag.

Oxygen Generating

The oxygen generating plant is a process for producing high purity (99.5%) oxygen in large tonnage rates for the steelmaking operations. Rates of 500 tons/day are common usage for the BOF plant. By means of compression and expansion, air is liquefied for separation of the oxygen and nitrogen. The liquid oxygen is stored and the nitrogen and other inert gases are ejected from the system. The waste from the oxygen plant is the heated cooling waters from compression equipment.

The various steelmaking operations are schematically shown in Figure 19.



PROCESS FLOW DIAGRAM
STEELMAKING
FIGURE 19

NOTE: ---- INDICATES ALTERNATE SYSTEMS

Table XIV Basic Oxygen Steelmaking Plants in the United States

ompany	Plant	In Operation	Plan	No. of Units	Size	Ann. Cap. Tons	Daily Cap. Tons	tap-to-tap (min.)	Est. no. of heats/da
an Wood Steel Corp.	Conshohocken	1968		2	140	1,250,000	3,425	58.9	24.5
Allegheny Ludlum Ind.	Brackenridge	1966		2	80	500,000	1,370	84.1	17.1
Armco Steel Corp.	Ashland	1963		2	180	2,000,000	5,479	47.30	30.4
Armco Steel Corp.	Middletown	1969		2	200	2,000,000	5,479	52.6	27.4
Bethlehem Steel Corp.	Bethlehem	1968		2	250	2,500,000	6,849	52.6	27.4
Bethlehem Steel Corp.	Sparrows Point	1966		2	200	2,600,000	7,123	40.4	35.6
Bethlehem Steel Corp.	Lackawanna	1964-66		3	290	4,700,000	12,876	64.9	44.4
Bethlehem Steel Corp.	Burns Harbor	1969		2	250	2,000,000	5,479	65.7	21.9
C.F. & I Steel Corp.	Pueblo	1961		2	120	1,200,000	3,288	52.6	27.4
Crucible Inc.	Midland	1968		2	90	900,000	2,466	52.6	27.4
Ford Motor Company	Rouge	1964		2	250	2,500,000	6,849	52.6	27.4
Granite City Steel Co.	Granite City	1967		2	225	2,200,000	6,027	53.8	26.8
Inland Steel Company	Indiana Harbor	1966		2	255	3,200,000	8,767	41.9	34.4
Inland Steel Company	Indiana Harbor		1973	2	210	2,200,000	6,027	50.2	28.7
Interlake Inc.	Riverdate Sta.	1959		2	75	750,000	2,055	52.6	27.4
I-H Wisconsin Steel	S. Chicago	1964		2	140	1,200,000	3,288	61.3	23.5
Jones & Laughlin Steel	Aliquippa	1957		2	80	1,000,000	2,740	42.0	34.3
Jones & Laughlin Steel	Aliquippa	1968		3	200	3,000,000	8,219	70.1	41.0
Jones & Laughlin Steel	Cleveland	1961		2	225	2,250,000	6,164	52.6	27.4

Table XIV (Cont.)

Company	Plant	In Operation	Plan	No. of Units	Size Tons	Ann. Cap. Tons	Daily/Cap. Tons	tap-to-tap (min.)	Est. no. of heat/day
Kaiser Steel Corp.	Fontana	1958		3	110	1,500,000	4,110	77.1	37.4
McLouth Steel Corp.	Trenton	1960		3	110	1,866,666	5,114	61.9	46.5
McLouth Steel Corp.	Trenton	1969		2	110	933,333	2,557	61.9	23.2
National Steel Corp.	Ecorse	1962		2	300	3,600,000	9,863	43.8	32.9
National Steel Corp.	Ecorse	1970		2	200	2,000,000	5,479	52.6	27.4
National Steel Corp.	Weirton	1967		2	335	3,400,000	9,315	51.8	27.8
Republic Steel Corp.	Warren	1965		2	185	2,100,000	5,753	46.3	31.1
Republic Steel Corp.	Cleveland	1966		2	240	2,600,000	7,123	48.5	29.7
Republic Steel Corp.	Buffalo	1970		2	100	1,000,000	2,740	52.6	27.4
Republic Steel Corp.	Gadsden	1965		2	190	1,500,000	4,110	66.6	21.6
U. S. Steel Corp.	S. Chicago	1969		3	200	3,000,000	8,219	70.1	41.1
U. S. Steel Corp.	Gary	1965		3	200	4,000,000	10,959	52.6	27.4
U. S. Steel Corp.	Gary	1971		3	200[1]	4,000,000	10,959	52.6	27.4
U. S. Steel Corp.	Duquesne	1963		2	190	2,500,000	6,849	46.3	31.1
U. S. Steel Corp.	Lorain	1970		2	220	2,250,000	6,164	51.4	28.0
U. S. Steel Corp.	Braddock	1972		2	220	2,250,000	6,164	51.4	28.0
Wheeling-Pittsburgh	Stubenville	1965		2	250	2,600,000	7,123	50.5	28.5
Wheeling-Pittsburgh	Monessen	1964		2	200	1,800,000	4,932	58.4	24.7
Youngstown Sheet &Tube	Indiana Harbor	1970		2	265	2,400,000	6,575	58.0	24.8
U. S. Steel Corp.	Birmingham		1973	2	200[2]				

1. These B.O.P. furnaces will be converted to Q-B.O.P. with start up expected in late 1972.
2. These are the Q-B.O.P. type steelmaking furnaces.

Table XV Electric Furnace Production Data

Company	Plant	No.	Size Tons	Annual Tons	Daily Tons	Tap-to-Tap Hours	Tons/ Minute
Inland Steel	Indiana Harbor	2	120	500,000	1,370	4.2	0.95
Keystone Steel & Wire	Peoria	2	150	600,000	1,644	4.4	1.14
Lukens Steel Company	Coatesville	1	150	297,840	816	4.4	0.57
CF&I Steel Corporation	Roebling	3	42.5	255,000	699	4.4	0.49
Jones & Laughlin Steel	Warren	1	65	84,355	231	6.75	0.16
Jones & Laughlin Steel	Warren	1	65	84,355	231	6.75	0.16
Jones & Laughlin Steel	Warren	1	65	73,470	201	7.75	0.14
Jones & Laughlin Steel	Warren	1	65	73,470	201	7.75	0.14
Jones & Laughlin Steel	Warren	1	65	73,470	201	7.75	0.14
Jones & Laughlin Steel	Warren	1	30	35,040	96	6.9	0.07
National Steel Corp.	Great Lakes	2	150	600,000	1,644	4.4	1.14
Bethlehem Steel Corp.	Los Angeles	2	100	404,040	1,106	4.3	0.77
Bethlehem Steel Corp.	Los Angeles	1	75	151,515	415	4.3	0.29
Armco Steel Corp.	Kansas City	1	113	259,296	710	3.82	0.49
Armco Steel Corp.	Kansas City	1	113	258,420	708	3.83	0.49
Armco Steel Corp.	Kansas City	1	161	330,252	905	4.27	0.63
Armco Steel Corp.	Houston	1	113	201,480	552	4.91	0.38
Armco Steel Corp.	Houston	1	113	211,116	578	4.69	0.40

STEELMAKING PRODUCTION FACILITIES

The capacities of steelmaking furnaces are given in terms of tons of steel produced per heat. In order to estimate production capacity from these data, it is necessary to know the duration of a heat, the number of furnaces operating at one time, and the tap-to-tap charge time, i.e., the time last between tapping a furnace and again charging it.

In Tables XIV and XV, production data are given from published sources for B.O.F. and electric furnaces. These data were used to calculate capacities for all other installations. For the B.O.P. plants, data are included for all plants so that no estimation is involved aside from the assumption that one vessel operates at a time in a 2-vessel shop, and 2 operate at a time in a 3-vessel shop. For electric furnaces, all furnaces are assumed operable at a time; only in a few cases do power supplies limit such a capability.

No such comprehensive data are available for open hearths. Heat times as follow have been reported.

Bethlehem Steel, Sparrows Ptl, Md.: 380 ton furnace, O_2 lanced - 8 hrs.
Steelco, Hamilton, Ont.: 500 ton furnace, O_2 lanced - 4 hrs.
U.S. Steel, Edgar Thomson Works: 200 ton furnace, O_2 lanced - 8.5 hrs.

Making and Shaping of Steel:

No oxygen - 10 hours

O_2 lanced - 9 hours.

Consideration of the open hearth process leads to the conclusion that assumptions of tap-to-tap times of 8 hours with oxygen-lancing and 12 hours without oxygen are probably the best averages. The older, smaller furnaces not only require longer heat times, but are found in shops where efficiency is lower and maintenance needs are higher. The open hearths being retired are, of course, the marginal operations, and those remaining will doubtless tend to be of even higher productive capacity. It must be remembered that the open hearth process is more labor-intensive than the B.O.P. or electric furnace processes. At least one hour between heats is used in tapping, ladle additions, refractory conditioning, hole repair, and reheating before the next charge begins. As the open hearth continues to compete with the newer processes, capacity increases as more oxygen, fuel enrichment, etc. are used, but the labor effort remains and productivity per man hour increases very little.

In Table XVI, the steelmaking facilities in 138 plants are summarized.

Table XVII summarizes the continuous costing facilities announced and gives the annual capacity of each.

Table XVI

Steelmaking Furnaces in the United States

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
Alan Wood Steel Corporation	Ivy Rock	Pa.	2			140	3425*	X	X			
Allegheny Ludlum Ind. Inc	Brackenridge	Pa.	2			80	1370*		X			(1) Hot Blast Cupula 5 st/hr.
		Pa.			4	10	168		X			
		Pa.			1	25	105		X	X		
		Pa.			2	35	150		X	X		
		Pa.			1	55	265		X	X		
		Pa.			2	70	690		X	X		
		Pa.			2	80	800		X	X		
Allegheny Ludlum Ind.Inc.	Dunkirk	N.Y.			2	25	210	X	X	X		
		N.Y.			1	15	63	X	X	X		
		N.Y.			1	12.5	52.5	X	X	X		
		N.Y.			1	2	8			X		
		N.Y.			1	1/5-1	4.2			X		Vacuum melt induction
		N.Y.			7	1/2-11	146		X	X		Vacuum melt electrode
Ajax Forging & Casting	Ferndale	Mich.			1	1	4.2		X			
		Mich.			1	4	16.8		X			
		Mich.			6	1/4-2	25.2		X			Induction
Special Metals Corporation	New Hardford	N.Y.			1	15	63		X			Vacuum Melt induction
		N.Y.			1	6	25.2		X			Vacuum melt induction
		N.Y.			3	1/2-2 1/2	18.9		X			Vacuum melt induction
		N.Y.			8	5	168		X			Consumable electrode
Allison Steel	Tempe	Ariz.			3	20	252	X				
American Compressed Steel	Cincinnati	Ohio			1	6	25.2	X				

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
Armco Steel	Ashland	Ky.	2			180	5,479*	X	X			
Armco Steel	Butler	Pa.			3	165	935	X	X	X		
		Pa.			1	70	370	X	X	X		
Armco Steel	Houston	Tex.		4		165	1,320	X	X		No oxygen	
		Tex.			2	113	1,130*	X	X			Wet scrubbers
		Tex.			4	175	3,880	X	X			
Armco Steel	Kansas City	Mo.			2	113	1,418*	X	X			
		Mo.			2	161	1,810*	X	X			
Armco Steel	Middletown	Ohio		6		310	5,580	X			Oxygen Plant 270,000 CFH	
		Ohio	2			200	5,479*	X				
Armco Steel	Sand Springs	Okla.			1	70	360	X				
Armco Steel	Baltimore	Md.			3	16	201.6		X	X		
		Md.			2	12	100.8		X	X		
		Md.			1	25	105		X	X		
		Md.			1	19	79.8		X	X		
Armco Steel	Torrance	Ca.			1	22.5	94.5	X	X	X		
		Ca.			1	6.0	25.2	X	X	X		
		Ca.			1	2.5	10.5	X	X	X		
Atlantic Steel	Atlanta	Ga.			2	85	920	X				
Babcock & Wilcox Co.	Beaver Falls	Pa.			2	25	210		X	X		
		Pa.			2	50	480	X	X	X		
		Pa.			2	75	780	X	X	X		
		Pa.			3	100	1,695	X	X	X		

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
Baldwin-Lima-Hamilton Corp.	Burnham	Pa.			1	40	175	X	X	X		
		Pa.			1	18	75.6	X	X	X		
		Pa.			1	45	200	X	X			
		Pa.			1	70	370	X	X			
		Pa.			1	11	46.2		X	X		
		Pa.			1	23	96.6		X	X		
Bethlehem Steel	Bethlehem	Pa.	2			250	6,849*	X	X			
		Pa.			1	7	29.4		X			Baghouse
		Pa.			1	28	117.6		X			
		Pa.			4	50	960		X			
Bethlehem Steel	Steelton	Pa.		3		150	900	X	X			
		Pa.		1		327	654	X	X		No oxygen	
		Pa.			1	5	21	X	X			
		Pa.			1	15	63	X	X			Baghouse
		Pa.			3	150	2,580	X	X			
Bethlehem Steel	Sparrows Point	Md.		7		420	8,820	X	X		Oxygen Plant-1,600,000CFH	
		Md.		11		276	9,108	X	X			
		Md.	2			200	7,123*	X	X			
Bethlehem Steel	Lacknanna	N.Y.		8		190	4,560	X	X		Oxygen Plant-1,535,000CFH	
		N.Y.		6		270	4,860	X	X			
		N.Y.	3			290	12,876*	X	X			
Bethlehem Steel	Johnstown	Pa.		8		180	4,320	X	X		Oxygen Plant-1,075,000CFH	
Bethlehem Steel	Burns Harb.	Ind.	2			300	5,479*	X	X			
Bethlehem Steel	Los Angeles	Ca.			1	75	390					
		Ca.			2	100	1,130	X	X			Baghouse
Bethlehem Steel	Seattle	Wash.			2	100	1,130	X	X			Baghouse

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
Border Steel Rolling Mills	Vinton	Texas			2	25	210	X				
Borg-Warner Corporation	Chicago Heights	Ill.			2	30	200	X				
Borg-Warner Corporation	New Castle	Ind.			2	9	75.6	X	X	X		
		Ind.			2	12	100.8	X	X	X		
Braeburn Alloy	Braeburn	Pa.			2	10	84	X	X			
		Pa.			1	11	46.2					30" vacuum consumable electrode arc remelt
Cabot Corp.	Pampa	Texas			1	10	42.0		X			
Cabot Corp.	Satellite	Ind.			3	1,5,5 1/2	86.1		X			
		Ind.			1	10	42.0		X			Vacuum Induction
		Ind.			2	17 1/2	147		X			Vacuum arc or esr electroslag
		Ind.			2	17 1/2	147		X			
Cameron Iron Works Inc.	Houston	Texas			1	60	285	X	X			
		Texas			2	25,60	390		X			Vacuum Induction
		Texas			20	16-34	2,100		X			Vacuum Consumable
Carpenter Tech.	Reading	Pa.			5	12	252	X	X	X		
		Pa.			1	1	4.2	X	X	X		
		Pa.			1	5	21	X	X	X		
		Pa.			1	1	4.2	X	X	X		
		Pa.			1	7.5	31.5	X	X	X		
		Pa.			2	2.5	21	X	X	X		
		Pa.			2	4	33.5	X	X	X		
		Pa.			6	9	226.8	X	X	X		

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
Carpenter Tech.	Bridgeport	Conn.			2	35	280	X	X	X		
Lemont Man.	Lemont	Ill.			3	30	300	X				
Milton Man.	Milton	Pa.			3	20	252	X				
Southern Elec.	Birmingham	Ala.			2	14	117.6	X	X			
C.F.&.I Steel	Pueblo	Colo.		8		110	2,640	X	X		Oxygen Plant-325TPD	
		Colo.		1		150	450	X	X			
		Colo.		1		185	555	X	X			
		Colo.	2			118	3,288*	X	X			
C.F.&.I. Steel	Roebling	N.J.			3	42.5	697*	X				
Columbia Tool Steel Company	Chicago Heights	Ill.			1	5	21		X Tool Steel			
		Ill.			1	8	33.6		X Tool Steel			
Continental Steel Corp.	Kokomo	Ind.			2	150	1,720	X				
Copperweld Steel Co.	Warren	Ohio			1	40	175	X	X	X		
		Ohio			3	47	615	X	X	X		
		Ohio			4	70	1,480	X	X	X		
Crucible, Inc.	Midland	Pa.	2			100	2,466*	X	X			Topoxygen conveters
Crucible Inc. S.S. Div.	Midland	Pa.			4	75	1,560	X	X	X		
		Pa.			1	25	105	X	X	X		
		Pa.			11	10	462		X	X		Electrode vacuum

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
Crucible, Inc.	Syracuse	N.Y.			1	35	140	X	X	X		
		N.Y.			4	15	252	X	X	X		
		N.Y.			1	1	4.2	X	X	X		Electric Induction
		N.Y.			2	1.5	12.6		X	X		Vac. melt. Induction
		N.Y.			2	10	84		X	X		Vac. melt. electrode arc remelting
Cyclops Empire Reevers Div.	Mansfield	Ohio		6		170	3,060	X	X		Oxygen Plant 150,000CFH	
		Ohio			2	100	1,130	X	X	X		
Cyclops Universal Div.	Bridgeville	Pa.			1	35	140	X	X	X		
		Pa.			4	12 3/4	214.2	X	X	X		
		Pa.			1	5	21	X	X	X		
		Pa.			2	6	50.4	X	X	X		
		Pa.			1	1.7	7.14	X	X	X		
		Pa.			1	1	4.2	X	X	X		
Detroit Steel	Portsmouth	Ohio		5		320	4,800	X			Oxygen plant 140,000CFH	
Eastern Stainless Steel Co.	Baltimore	Md.			2	3 1/4	27.3		X	X		Electric induction
		Md.			2	15	126		X	X		
		Md.			1	50	240		X	X		
		Md.			1	1 1/2	6.3		X			Vac. melt induction
		Md.			1	5	21		X			Vac. melt cons. electrode
Edgewater Corp.	Oakmont	Pa.			1	45	190	X				
Latrobe Forge & Spring Inc.	Latrobe	Pa.		2 (acid)		62	248	X	X		No oxygen	

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
Etiwanda Steel Products Co.	Etiwanda	Ca.			2	12	100.8	X	X			C.C 2 strand
Florida Steel	Tampa	Flo.			1	35	140	X				
		Flo.			2	15	126	X				
Ford Motor Co.	Rouge	Mich.	2			240	6,849*	X	X			
Georgetown Steel Corp.	Georgetown	S.C.			2	65	620	X	X			
Granite City Steel Co.	Granite City	Ill.	2			220	6,027*	X				
H.M. Harper Co.	Morton Grove	Ill.			1	10	42		X			Electric
		Ill.			1	4	16.8		X			Electric Induction
		Ill.			1		4.2		X			
Harrisburg Steel	Harrisburg	Pa.		3		50	300	X	X		No oxygen	
Hawaiian Western Steel		Hawaii			1	15	63	X				
Heppenstall Co.	Pittsburgh	Pa.		2 (acid)		40	160	X	X		No oxygen	
Midvale-Heppenstall Co.	Philadelphia	Pa.			1	30	100	X	X	X		
		Pa.			1	50	240	X	X	X		
		Pa.			1	100	565	X	X	X		Vacuum electrode
		Pa.			2	5	42	X	X	X		Vacuum electrode
		Pa.			1	25	105	X	X	X		
Inland Steel Co.	Indiana Harbor	Ind.		24		210	10,800	X	X		Oxygen plant-not listed	
		Ind.		7		335	4,690	X				
		Ind.	2			255	8,767*	X				
		Ind.			2	120	1,370*	X	X			

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
Intercoastal Steel Corp.	Chesapeake	Va.			2	20	168	X				
Interlake, Inc	Riverdale Station	Ill.	2			75	2,055*	X				
Interlake, Inc.	Wilder	Ky.		2		78	468	X			Oxygen plant-27,000CFH	
		Ky.		5		97	1,455	X				
		Ky.			3	75	1,170	X	X			
I-H Wisc. Steel	S. Chicago	Ill.	2			140	3,288*	X	X			
Jessop Steel	Washington	Pa.			1	16	67.2	X	X			
		Pa.			2	14	117.6			X		
		Pa.			1	8	33.6	X	X			
		Pa.			1	1/2	2.1	X	X			Elec. induction
		Pa.			1	1	4.2	X	X			Elec. & vac. melting
		Pa.			1	2 1/2	10.5	X	X			Elec. & vac. melting
		Pa.			1	2 1/2	10.5	X	X			Elec. & vac. melting
Greenriver Steel Corp.	Owensboro	Ky.			2	60	580	X	X	X		
Jones & Laughlin Steel	Aliquippa	Pa.	2			82	2,740*	X	X			
		Pa.	3			207	8,219*	X	X			
Jones & Laughlin Steel	Pittsburgh	Pa.		11		350	11,550	X	X		Oxygen Plant-340,000CFH	
		Pa.			1	2	8.4	X	X	X		
Jones & Laughlin	Cleveland	Ohio	2			230	6,164*	X				
		Ohio			2	150	1,720	X				

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
Jones & Laughlin Steel	Warren	Mich.			5	65	1,065*		X	(X)		
		Mich.			1	30	96*			(X)		
Earlem Jorgensen Company	Seattle	Wash.			2	40	350	X	X	X		
Joslyn Stainless Steel	Chicago	Ill.			1	20	84			X		
		Ill.			2	15	126			X		
Judson Steel	Emeryville	Ca.			1	45	190	X				
Kaiser Steel	Fontana	Ca.		8		225	5,400	X	X		Oxygen plant-750,000CFH	
		Ca.	3			110	4,110*	X	X			L-0 Oxygen Process
Kentucky Elec. Steel Co.	Coalton	Ky.			2	15	126					
Keystone Steel and Wire	Peoria	Ill.		5		175	1,750	X			No oxygen	
		Ill.			2	150	1,644*	X				
Laclede Steel	Alton				2	200-225	1,785	X				
Latrobe Steel	Latrobe	Pa.			3	4-30	214.2	X	X			Vacuum induction
		Pa.			1	1	4.2	X	X			Vacuum induction
		Pa.			1	30	100	X	X			
Le Tourneau	Longview	Texas			3	27	340.2	X	X			
Lone Star Stee	Long Star	Texas		5		250	3,750	X			Oxygen plant-400,000CFH	
Lukens Steel	Coatesville	Pa.		6		145	2,610	X	X		Oxygen plant-capacity not listed	
		Pa.			1	145	816*	X	X			
		Pa.			2	100	1,130	X	X			

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
McLouth Steel	Trenton	Mich.			2	200	1,680	X		X		
		Mich.	5			110	7,671*	X		X		
Mesta Machine	W. Homestea	Pa.		1 (acid)		40	80	X	X		No oxygen	
		Pa.		1 (acid)		50	100	X	X			
		Pa.		2 (acid)		125	500	X	X			
		Pa.			1	12	63	X	X			
Mesta Machine	New Castle	Pa.		1 (acid)		35	70	X	X		No oxygen	
		Pa.		2 (acid)		50	200	X	X			
		Pa.		1 (acid)		100	200	X	X			
Miss. Steel Div. Magna	Flowood	Miss.			2	10	84	X				
National Forge	Irvine	Pa.			1	20	84	X	X			
		Pa.			1	45	190			X		
National Forge	Erie	Pa.			1	35	120	X	X	X		
					2	75	630	X	X			
National Steel Corp. Great Lakes Div.	Ecorse	Mich.	2			200	5,479*	X	X			
		Mich.	2			300	9,863*	X	X			
		Mich.			2	150	1,644*	X	X			Spray chamber & Baghouse
National Steel Corp. Weirton Steel Div.	Weirton	W. Va.		1		500	1,500	X			Oxygen plant 1,200,000CFH	Open Hearth shop presently inactive
		W. Va.		2		550	3,300	X				
		W. Va.		1		600	1,800	X				
		W. Va.	2			335	9,315*	X				
North Star Steel Co.		Minn.			2	60	780	X	X			
Northwest Stee Rolling Mills	Kent	Wash.			1	30	100	X				

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
Northwest Steel & Wire	Sterling	Ill.			2	150	1,730	X				
		Ill.			1	250	1,050	X				
		Ill.			1	400	1,680	X				
Pacific States Steel Corp.	Union City	Ca.		4		150	1,800	X	X		Oxygen plant-135,000CFH	
Phoenix Steel	Claymont	Del.			2	150	1,730	X	X	X		
Phoenix Steel	Phoenix-ville	Pa.		5		150	1,500	X	X		No oxygen	
H. K. Porter Co. Connors Steel Div.	Birmingham	Ala.			1	15	63	X				
		Ala.			2	18	151.2	X				
Connors Steel	Huntington	W. Va.			2	30	200	X	X			
Republic Steel	Warren	Ohio	2			150	5,753*	X	X			
					2	185	1,554	X	X			
Republic Steel	Canton	Ohio			5	80	2,050	X	X	X		Top Charge
		Ohio			4	200	3,360	X	X	X		2 Top charge
		Ohio			8	5-20	470.4		X	X		Top Charge Vac. melt electrode
Republic Steel	Cleveland	Ohio	2			220	7,123*	X	X		Oxygen plant-1,150,000CFH	
		Ohio		4		400	4,800	X	X			
Republic Steel	Buffalo	N.Y.	2			100	2,740	X	X			
Republic Steel	S. Chicago	Ill.		4		250	3,000	X	X		Oxygen plant 400,000CFH	
		Ill.			1	145	850	X	X			
		Ill.			3	150	2,580	X	X			

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
Republic Steel	Gulfsteel (Gadsen)	Ala.	2			150	4,110*	X	X			
		Ala.			2	185	1,554	X	X			
Finkl & Sons	Chicago	Ill.			2	65	620	X	X			Top Charge
Roblin Steel	Dunkirk	N.Y.			2	25	210	X	X			
Sharon Steel	Farrel	Pa.		11		150	4,950	X	X			
		Pa.	2			150	4,200	X	X		Oxygen plant 520,000CFH	
		Pa.			2	110	1,190		X	X		
Owen Elec. Steel Co.	Columbia	S.C.			X							
Simonds Steel Div. Wallace Murray	Lockport	N.Y.			3	15	189	X	X	X		
		N.Y.			1	1	4.2		X			Elec. Induction
		N.Y.			1	1/2	2.1		X			Elec. Induction
		N.Y.			2	5	42		X			Consum. Electrode
Soul'e Steel	Long Beach	Ca.			2	15	126	X				
Southwest Stee Rolling Mills	L. Angeles	Ca.			1	18	75.6	X				
		Ca.			1	15	63	X				
Structural Metals,Inc.	Seguin	Texas			2	25	210	X				
Tenn. Forging Steel Corp.	Harriman	Tenn.			2	25	210	X	X			
Texas Steel Co	Fort Worth	Texas			1	4	16.8	X	X			
		Texas			1	12	50.4	X	X			
		Texas			1	3	12.6	X	X	X		
		Texas			2	25	210	X				

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
Timken Steel & Tube Div. Timken Company	Canton	Ohio			1	140	760	X	X	X		
		Ohio			4	110	2,380	X	X	X		
		Ohio			1	60	290	X	X	X		
		Ohio			2	40	350	X	X	X		
		Ohio			1	4	16.8	X	X	X		
		Ohio			1	19		X	X	X		
Union Electric Steel Corp.	Carnegie	Pa.			1	35	79.8		X			
U.S. Steel	Homestead	Pa.		14		145	4,060	X	X		No oxygen plant listed	
		Pa.		11		320	7,040	X	X			
U.S. Steel	Johnstown	Pa.			1	30	100	X	X	X		
					2	3	25.2	X	X	X		
U.S. Steel	S. Chicago	Ill.		14		265	11,130	X	X		Oxygen plant 1,200TPD	
		Ill.	3			150	8,219*	X	X			
		Ill.			1	46	200	X	X	X		
		Ill.			2	85	930	X	X	X		
U.S. Steel	Braddock	Pa.		16		205	6,550	X	X		No oxygen plant listed	
U.S. Steel	Fairfield	Ala.		12		230	8,280	X	X		Oxygen plant 310,000CFH	
		Ala.		9		150	4,050	X	X			
		Ala.		3 (Bessemer)		24		X				
U.S. Steel	Fairless	Pa.		9		395	10,665	X	X		Oxygen plant 270,000CFH	
U.S. Steel	Gary	Ind.		14		150	6,300	X	X		Oxygen plant 1,260,000CFH	
		Ind.		8		165	3,960	X	X			
		Ind.		6		205	3,690	X	X			
		Ind.		6		190	3,420	X	X			
		Ind.		2		300	1,800	X	X			
		Ind.		2		20	FOUNDRY					
		Ind.	3				13,699*	X	X			

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
U.S. Steel	Geneva	Utah		10		340	10,200	X	X		Oxygen plant cap. not listed	
U.S. Steel	Torrance	Ca.		4		63	504	X			No oxygen plant listed	
U.S. Steel	McKeesport	Pa.		3		192	1,152	X			No oxygen plant listed	
		Pa.		3(Bessemer)		29		X				
U.S. Steel		Texas			2	200	1,680					
U.S. Steel	Duquesne	Pa.	2			190	6,849*	X	X			3 Place vacuum Casting facility Elec. furnaces
		Pa.			1	17.5	73.5		X	X		
		Pa.			1	43	185		X	X		
		Pa.			3	85	1,395		X	X		
U.S. Steel	Lorain	Ohio		12		190	6,840	X	X		Oxygen plant 240,000CF/HR	
		Ohio	2			220	6,164	X				
U.S. Steel	Youngstown	Ohio		15		162	7,290	X	X		Oxygen plant 224,000CFH	
U.S. Steel	Duluth	Minn.		9		150	4,050	X	X		Oxygen plant 14,000CFH	
Teledyne Allvac	Monroe	N.C.			2	7 1/2	53	X	X			Vacuum Arc.
		N.C.			1	1 1/2	6.3	X	X			Vacuum Arc.
		N.C.			3	5,000T	13.7	X	X			Vac. Melt Electrode
		N.C.			1	per year		X	X			Vac. Melt Electrode

COMPANY	PLANT	STATE	TYPE OF STEELMAKING (# of units)			SIZE-TONS PER HEAT, PER VESSEL	CAPACITY-TONS PER DAY	GRADE PRODUCED			OXYGEN FAC.	REMARKS
			B.O.F.	OPEN HEARTH	ELECT.			CARBON	ALLOY	SS		
Teledyne Vasco	Latrobe	Pa.			1	1/20	.2	X	X			Electric induction
		Pa.			1	1/8	.5	X	X			Electric induction
		Pa.			1	1/2	2.1	X	X			Electric induction
		Pa.			1	1	4.2	X	X			Electric induction
		Pa.			2	4	33.6	X	X			Electric Arc
		Pa.			2	15	63	X	X			Vac. Melt., electrode
		Pa.			1	13	54.6	X	X			Vac. Melt, electrode
		Pa.			1	4 1/2	18.9	X	X			Vac. Melt, electrode
		Pa.			1	1/10	.4	X	X			Vac. Melt, electrode
Washington Steel Corp.	Houston	Pa.			2	35	230			X		
Wheeling-Pgh Steel Corp.	Stubenville	Ohio		11		215	7,095	X	X		Oxygen plant 900,000LFH	
		Ohio	2			250-300	7,123*	X	X			
Wheeling-Pgh. Steel Corp.	Mdnessen	Pa.		8		220	5,280	X	X		Oxygen plant 400,000CFH	
		Pa.	2			200	4,932*	X	X			
Youngstown S&T	Campbell	Ohio		12		210	7,560	X	X		Oxygen Plant 325,000CFH	
Youngstown S&T	Youngstown	Ohio		11		175	5,775	X	X		Oxygen plant 27,000EFH	
Youngstown S&T	Ind. Harbor	Ind.		8*		315	7,560	X	X		Oxygen plant 915,000EFH	
		Ind.	2			265	8,219*	X	X			

*STAND BY

Table XVII
Continuous Casting Plants in the United States

Company	Location	Start	Slabs	Other	Carbon	Alloy	Stainless	Capacity tons/yr.
Armco Steel Corp.	Butler, Pa.	1971	X					
Armco Steel Corp.	Middletown, O.	1972	X					200,000
Armco Steel Corp.	Sand Springs, Okl.	1965		X	X			180,000
Bethlehem Steel	Johnstown, Pa.	1970		X	X	X		200,000
Borg Warner Corp.	Chicago Hghts., Ill.	1967		X	X			250,000
H. K. Porter Co.	Birmingham, Ala.	1964		X	X			230,000
Copperweld Steel	Warren, Ohio	1965		X		X		270,000
Crucible Steel Co.	Midland, Pa.	Future	X		X	X	X	
Etiwanda Steel	Etiwanda, Calif.	1967		X	X			
Florida Steel Corp.	Tampa, Florida	1965		X	X			100,000
Florida Steel Corp.		Future		X	X			90,000
Georgetown Steel	Georgetown, S.C.	1969		X	X			125,000
Georgetown Steel	Georgetown, S.C.	1970		X	X			
Inland Steel Co.	E. Chicago, Ind.	1971		X	X	X		500,000
Inland Steel Co.	E. Chicago, Ind.	1972	X		X			1,000,000
Jones & Laughlin	Aliquippa, Pa.	1969		X	X			1,200,000
Keystone Steel & Wire	Peoria, Ill.	1968		X	X			325,000
Kentucky Electric	Ashland, Ky.	Future		X	X			120,000
Knoxville Iron Co.	Knoxville, Tenn.	Future		X				
Laclede Steel Co.	Alton, Ill.	1967	X	X	X			800,000
Lukens Steel Co.	Coatesville, Pa.	1972	X					450,000
McLouth Steel Corp.	Trenton, Mich.	1964	X		X		X	
McLouth Steel Corp.	Trenton, Mich.	1969	X		X		X	
National Steel Corp.	Ecorse, Mich.	1969		X	X			
Weirton Steel	Weirton, W. Va.	1968	X					1,500,000
North Star Steel	St. Paul, Minn.	1967		X	X			120,000
North Star Steel	St. Paul, Minn.	Future		X				180,000
Nuclear Corp.	Dovesville, S.C.	1969		X	X			60,000
Phoenix Steel	Claymont, Del.	1968	X		X	X		525,000
Pollak Steel Co.	Marion, Ohio	1968			X			
Republic Steel	Canton, Ohio	1968		X	X	X	X	300,000
Republic Steel	Canton, Ohio	1968	X			X	X	
Roanoke Electric	Roanoke, Va.	1963		X	X			72,000
Roblin Steel Corp.	Duakirk, N.Y.	1964		X	X	X		120,000
Soule Steel Co.	Long Beach, Calif.	1966		X	X			36,000
Tennessee Forging	Harriman, Tenn.	1967		X	X			36,000
Timken Roller Bearing	Canton, Ohio	1968		X		X		
U.S. Steel Corp.	S. Chicago, Ill	1970		X	X			
U.S. Steel Corp.	Gary, Ind.	1967	X					
U.S. Steel Corp.	Torrance, Calif.	1968	X	X	X			200,000
U.S. Steel Corp.	Texas Works	1972	X					
U.S. Steel Corp.	Fairless Works	1972		X				
Wisconsin Steel	Chicago, Ill.	1966		X	X			400,000

WASTEWATER TREATMENT METHODS AND WASTE LOADS

The wastewater treatment methods available include plain sedimentation, sedimentation-flocculation, deep bed filtration, and reuse of wastewater. Flocculation may be accomplished by the use of chemicals such as ferric sulfate and lime, polyelectrolytes, and/or magnetic agglomeration.

When a water quench is used, about 5-8 gpm per ton of steel results from this source alone. 35 gpm per ton is required for quenching plus scrubbing in a venturi scrubber. About 0.5 gpm per ton is blowdown from such a system (containing 20 ppm suspended solids) and 0.4 gpm per ton is lost as vapor in the gas (I. & S. Engr., Sept., 1969). The same reference indicates an average of 13 gpm per 1,000 scfm of gas in a venturi scrubber.

Another reference (I. & S. E., July, 1961) gives operating data for a 160-ton B.O.F. producing 1,200,000 tons of steel annually. A water rate of 700 gpm is given for quenching with 1,400 gpm for the venturi scrubber. A blowdown (and make up) rate of 200 gpm is given with the blowdown containing 4% suspended solids. The indicated tap-to-tap time is 1.168 hours.

The B.O.F. shop at Interlake Steel Corporation in Chicago has a two furnace B.O.F. shop with 75-ton furnaces, and uses 1,000 gpm of water for quenching prior to a dry precipitator.

Wet scrubbers on B.O.F.'s are normally operated with about 75% excess air, while dry precipitators require 150% excess air to insure combustion of carbon monoxide. With 75% excess air, the total waste gas volume will be 9.33 std. ft.^{3} per ft.^{3}

of oxygen blown. A venturi scrubber requires 8 gpm of water per 1,000cfm of gas, while a quencher typically requires 4 gpm per 1,000 cfm. The gas leaving the furnace will be about 3,000°F.

Oxygen rates for several B.O.F.'s have been reported as follows:

Plant	Furnace Size	O_2 Time in mins.	Off-gas volume rate
Bethlehem Bethlehem, Pa.	2-250	19	20,000cfm
Combustion (Nov. 1967)	200-ton	--	20,000 scfm
Republic, Gadsden	2-190	--	2,000 ft.^{3} per ton O_2
Alan Wood Steel	2-140	15	12,000cfm O_2
Bethlehem Buns Harbor	2-250	--	27,500scfm O_2
Wheeling-Pgh., Monessen	2-200	18	18,000cfm O_2
Colorado Fuel & Iron	2-120	--	10,000cfm O_2
U. S. Steel, Duquesne	2-220	--	125,000scfm, venturi stack
Rowe, et. al.	2-300	22	32,000scfm, O_2
Weirton	2-340	--	1,739ft.^{3} per ton O_2

At an average oxygen-blowing time of 18.5 minutes for the above which are unspecified, the above data indicate an average oxygen rate of 1,775 cubic feet of oxygen per ton of steel. The total gas volume is thus indicated to average about 16,561 std. ft.^{3} per ton of steel. A typical wet scrubber operation has gas volumes and water flow rates as follow:

Vessel off-gases: 65,000scfm @3200°F (dry)
Venturi inlet: 177,000cfm @183°F (sat'd.)
Stack volume: 80,000cfm @110°F

The gas volume of the venturi inlet thus averages about 45,000 cubic feet per ton of steel. The water uses would thus be expected to be 360 gallons per ton for scrubbing and 180 gallons per ton for quenching, totaling 540 gallons per ton.

Water requirements for a B.O.F. using electrostatic precipitators and an evaporation chamber total 3,200gpm for 2-250 tons vessels producing 2,300,000 tons per year, or 6,301 tons per day, indicating a use of 731 gallons per ton. A survey of British plants indicated a mean water use of 2,885 gallons per ton in pneumatic steelmaking processes. At least one B.O.F. shop on the Great Lakes uses as much as 4,900 gallons per ton for cooling; this B.O.F. uses 438 gallons per ton for gas scrubbing.

The B.O.F.'s and continuous casters at Weirton use 50 mgd of water, producing 9,315 tons per day, i.e., use 5,368 gallons per ton. Assuming 2,800 gallons per ton for the caster and 540 gallons per ton for gas cleaning, the B.O.F. cooling water would be 2,028 gallons per ton.

An average cooling water use of 2,000 gallon per ingot ton for B.O.F.'s seems to be indicated.

Cooling water use for open-hearths and electric furnaces are best estimated from the U.S.G.A. survey data at 4,950 and 2,720 gallons per ton, respectively. British data tend to be in the same ratios as these figures to those previously given for for B.O.F. cooling.

One electric furnace installation using venturi scrubbers on very large furnaces, uses about 1,330 gallons per ton. This is probably a maximum figure applying to only the largest furnaces. Of the total, 25% is used in the quencher and the remainder in the scrubber.

A 200-ton open hearth at Edgar Thomson Works, U. S. Steel, used 500gpm in a venturi scrubber during an 8.5-hour heat. This is equal to 1,275 gallons per ton of steel.

The scrubbers on the No. 7 and No. 8 open hearths at Youngstown Sheet and Tube, Indiana Harbor handle gas flows of 70,000scfm at 1,500°F with oxygen rates of 900 $ft.^3$ per ton. Each furnace averages 45 tons per hour of production at heat times of 7.2 hours. The exhaust fan for the common cooling tower is rated at 93,000cfm at 41" suction; the fan outlet volume would thus be about 80,000cfm. Assuming a total water use of 10gpm per scfm, a use here of 933 gallons per ton is indicated.

When the OG (off-gas) system is used with a B.O.F., as at Armco, Middletown, the scrubbers are about 25% as large as with a conventional system. The gas volumes are 25% as great and the temperatures are about the same as with the use of 75% excess air.

A water quencher will scrub some of the particulate matter from the gas. The cleaning efficiency is, of course, not very good. There are little or no data available, but there is an indication in the data from the Interlake installation that about 25% of the particulates generated are relatively large particles which would probably be washed out of the gas by the crudest type of washer.

At Inland Steel in East Chicago, the total water use for a two furnace shop producing 9,888 tons per day is 70mgd. The water uses are as follow:

Hood Cooling: 23.0 mgd = 2,330 gallons/ton
Lance Cooling: 5.18 mgd = 524 gallons/ton
Spark box sprays: 2.23 mgd = 226 gallons/ton
Scrubbing
Final Cooling 39.6 mgd - 4,003 gallons/ton

The B.O.F. shop at Lackawanna uses 9,400 gpm when the 2 furnaces are producing 290-ton heats simultaneously, and 7,000 gpm when one furnace is operating. The O_2 blowing time is 21 minutes, or 507 gallons per ton of steel.

One 300-ton open hearth at Buffalo uses a minimum of 600 gpm on a venturi scrubber. Assuming a 7-hour heat, the water use is 840 gallons/ton.

Considering all of the above data, Standard Raw Waste Loads are estimated in Table XVIII, The data for continuous casting and vacuum degassing are taken from the report of NUS Corporation as shown in Tables XIX and XX.

Table XVIII

Steel Making Waste Loads

			Cooling Water gal/ton	Effluent Process Water gal/ton	Waterborne Solids #/ton
Basic Oxygen Furnace	Evaporation Chamber	Precipitator	2,000	0	0
Basic Oxygen Furnace	Quencher	Precipitator	2,000	180	10
Basic Oxygen Furnace	Quencher	Venturi Scrubber	2,000	540	41
B.O.F. (O-G System)	Quencher	Venturi Scrubber	2,000	135	41
Electric Furnace	Evaporation Chamber	Precipitator	2,720	0	0
Electric Furnace	Quencher	Venturi Scrubber	2,720	1,330	11.7
Open-Hearth	Evaporation Chamber	Precipitator	4,950	0	0
Open-Hearth	Quencher	Venturi Scrubber	4,950	1,000	25
All Furnaces	Evaporation Chamber	Bag Houses	--	0	0
Continuous Casting	--	--	2,000	800	30
Vacuum Degassing	--	--	150	260	0.75

TABLE XIX

STEEL MANUFACTURING

CONTINUOUS CASTING EFFLUENT

STANDARD RAW WASTE LOAD

Tons/Day	1,000 - 5,700	
Parameters	**Range**	**Average**
Water Flow(1)		
Cooling Water Gal/Ton	1,500-2,500	2,000
Process Water Gal/Ton	600-1,000	800
Total Water Gal/Ton	2,100-3,500	2,800
Suspended Solids(2)		
mg/l	3,000-7,500	4,500
Lbs/Ton	20 - 50	30

(1) Flow given is circulating water rate. All water is used for cooling. The process water comes in contact with the steel and picks up suspended solids and possibly a trace of oil. The cooling water is indirect cooling water. Generally all water is handled in recirculating cooling towers which would have a toal evaporation and blow down loss of 2% to 3% of the circulating rate. Heat removal is about 200 BTU/Lbs of steel cast.

(2) Based on process water only.

Table XX

STEEL MANUFACTURING
VACUUM DEGASSING EFFLUENT
STANDARD RAW WASTE LOAD

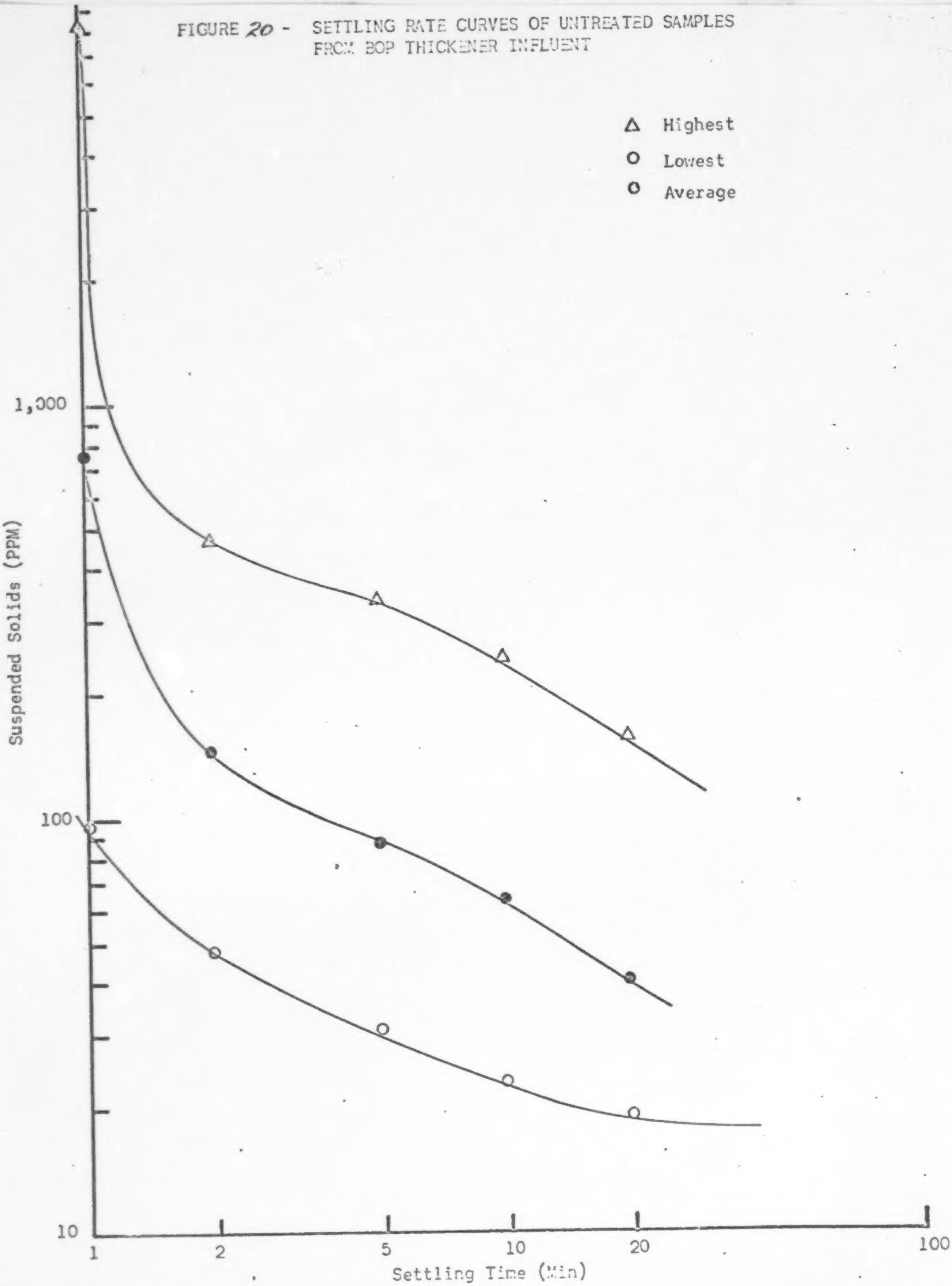
Tons/Day 1,000-5,700

Parameters	Range	Average
Water Flow Cooling Water Gal/Ton	100-200	150
Process Water Gal/Ton	225-300	260
Total Water Gal/Ton	325-500	410
Suspended Solids		
mg/l	125-700	350
Lbs/Ton(2)	0.25-1.5	0.75

(1) Based on process water only.

(2)Lbs./Ton calculated from mg/l based on average water flow.

FIGURE 20 - SETTLING RATE CURVES OF UNTREATED SAMPLES FROM BOP THICKENER INFLUENT



Present Practice Waste Loads:

Many present steelmaking operations use only plain sedimentation to treat steelmaking wastewaters. Settling rate curves are typically as shown in Figure 20 and the S.I. value of the typical thickener is 10 minutes, indicating an average effluent concentration of 65 ppm. The SPWL for the various steelmaking operations are thus indicated to be as follows:

Furnace	System	Flow, gal./ton	Load, #/ton
B.O.F.	Precipitator-Quencher	180	0.097
B.O.F.	Venturi-Quencher	540	0.292
B.O.F.	O-G System	135	0.073
Electric	Venturi-Quencher	1,330	0.720
Open-Hearth	Venturi-Quencher	1,000	0.541

No specific data are available, in any usable form, for wastewaters from slab casting. Since, however, wastewater volumes are essentially the same as for conventional slab mills, the critical finer suspended particle concentrations should be similar.

The fume generated in vacuum degassing should be at least as fine as that of the average from the B.O.F. vessel. That 350 ppm, diluted from 260 gallons per ton to 1,060 gallons per ton would contribute 86 ppm to the effluent of a scale pit having an S.I. of 1 minute. A typical blooming or billet mill scale pit with an S.I. of 1 minute will not have an effluent containing less than 100ppm; similar values would be expected from a slab mill. A SPWL then of 1,060 x 8.33 x 86 x 10^{-6}, or 1.64 lbs. per ton of steel would be expected.

Best Practicable Treatment Waste Loads:

The best practicable treatment without water reuse is sedimentation-flocculation. Effluents of 15ppm or less are being achieved. Assuming that the effluent from the steelmaking furnace and the slab casting/vacuum degasser would be combined for treatment in an adequate clarifier, the waste loads would be:

Furnace	System	Flow, gal/ton	Load,#/ton
B.O.F.	Precipitator-Quencher	1,240	0.155
B.O.F.	Venturi-Quencher	1,600	0.200
B.O.F.	O-G System	1,195	0.149
Electric	Venturi-Quencher	2,390	0.299
Open-Hearth	Venturi-Quencher	2,060	0.257

From the steelmaking process alone:

Furnace	System	Flow, gal/ton	Load,#/ton
B.O.F.	Precipitator-Quencher	180	0.022
B.O.F.	Venturi-Quencher	540	0.067
B.O.F.	O-G System	135	0.017
Electric	Venturi-Quencher	1,330	0.166
Open-Hearth	Venturi-Quencher	1,000	0.125

Best Available Treatment:

The Best Available Treatment is recirculation and reuse of the treated effluent. Although the blowdown can probably be much lower, it is clear that it can be at least as low as 20%. On this basis, the BAT waste loads would be:

Furnace	System	Steelmaking Only		Furnace + Casting	
		gal/ton	#/ton	gal/ton	#/ton
B.O.F.	Precipitator-Quencher	36	0.004	248	0.031
B.O.F.	Venturi-Quencher	108	0.013	320	0.040
B.O.F.	O-G System	27	0.003	239	0.030
Electric	Venturi-scrubber	266	0.033	478	0.060
Open-Hearth	Venturi-scrubber	200	0.025	412	0.051

STEELMAKING TREATMENT COSTS

The costs of treating steelmaking wastewaters are similar, on a unit cost basis, to those for treating blast furnace and sinter plant effluents. These costs are best given in terms of wastewater volumes of representative flow rates, since various combinations of processes can be found in steelmaking operations.

Capital Costs: (1972 $ per annual ton)

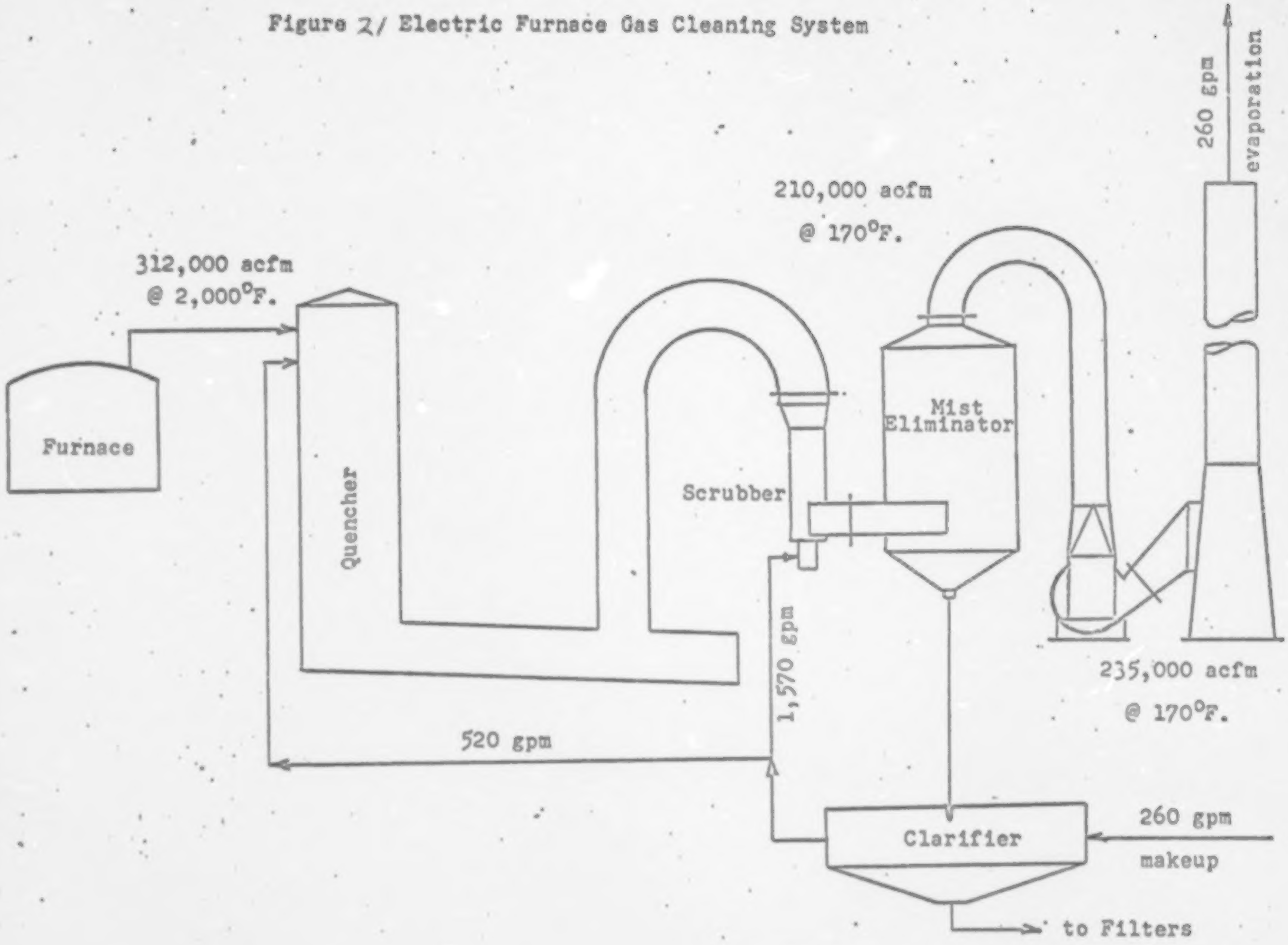
	Wastewater Volume, gals. per ton				
	500	1000	1500	2000	2500
Plain Sedimentation:	$0.71	$1.09	$1.39	$1.65	$1.89
Coagulation-Sedimen.	0.79	1.22	1.56	1.85	2.11
Recirculation and:					
Plain Sedimen.	0.85	1.32	1.68	2.00	2.29
Coagulation-Sedimen.	1.02	1.58	2.02	2.39	2.74

Operating Costs: (1972 $ per ton)

	Wastewater Volume, gals. per ton				
	500	1000	1500	2000	2500
Plain Sedimentation:	$0.18	0.28	0.35	0.42	0.48
Coagulation-Sedimen.	0.28	0.43	0.55	0.66	0.75
Recirculation and:					
Plain Sedimen.	0.18	0.28	0.35	0.42	0.48
Coagulation-Sedimen.	0.28	0.43	0.55	0.66	0.75

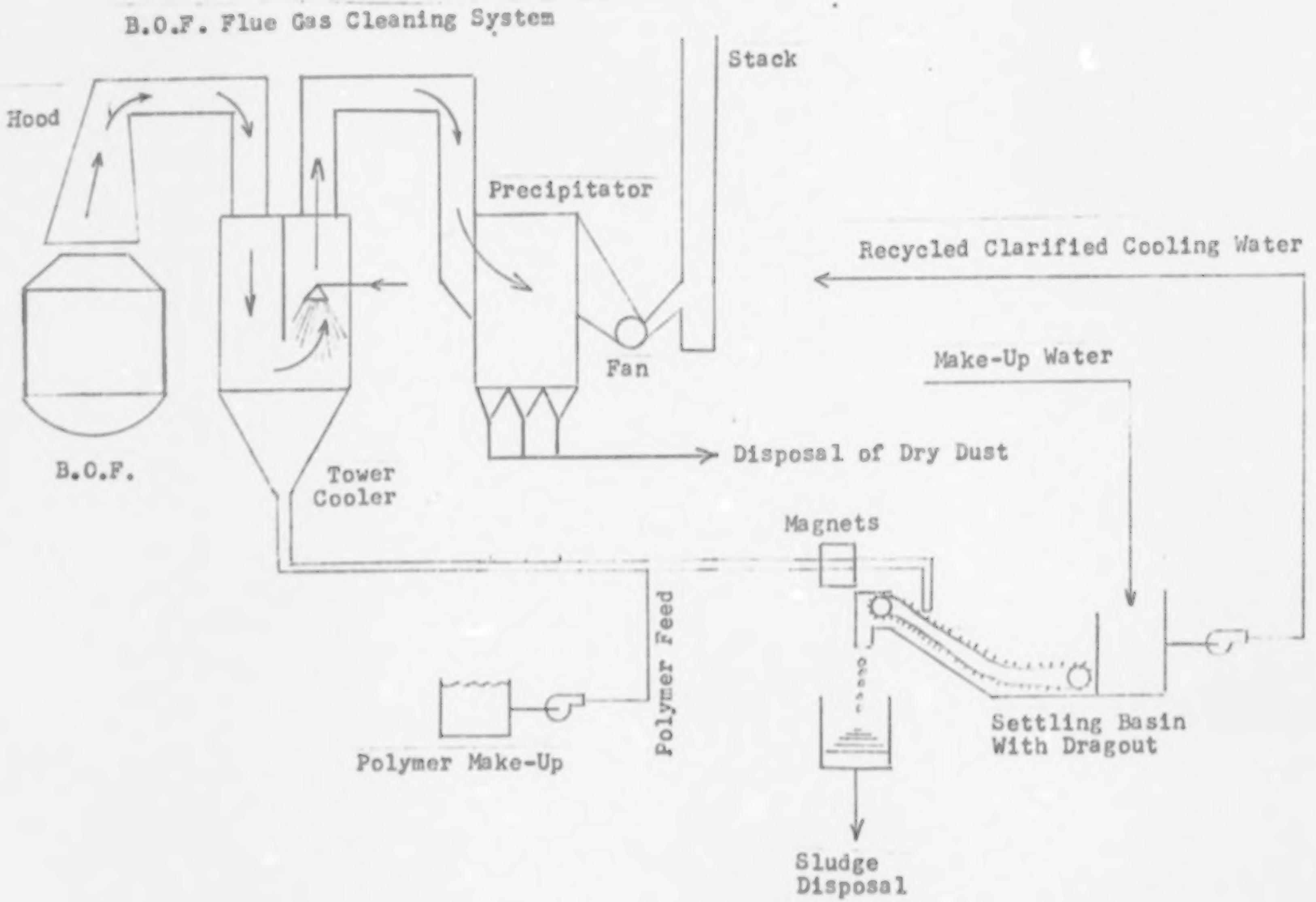
Gas cleaning and wastewater treatment systems for steelmaking furnaces are illustrated in Figures 21, 22 and 23.

Figure 2/ Electric Furnace Gas Cleaning System



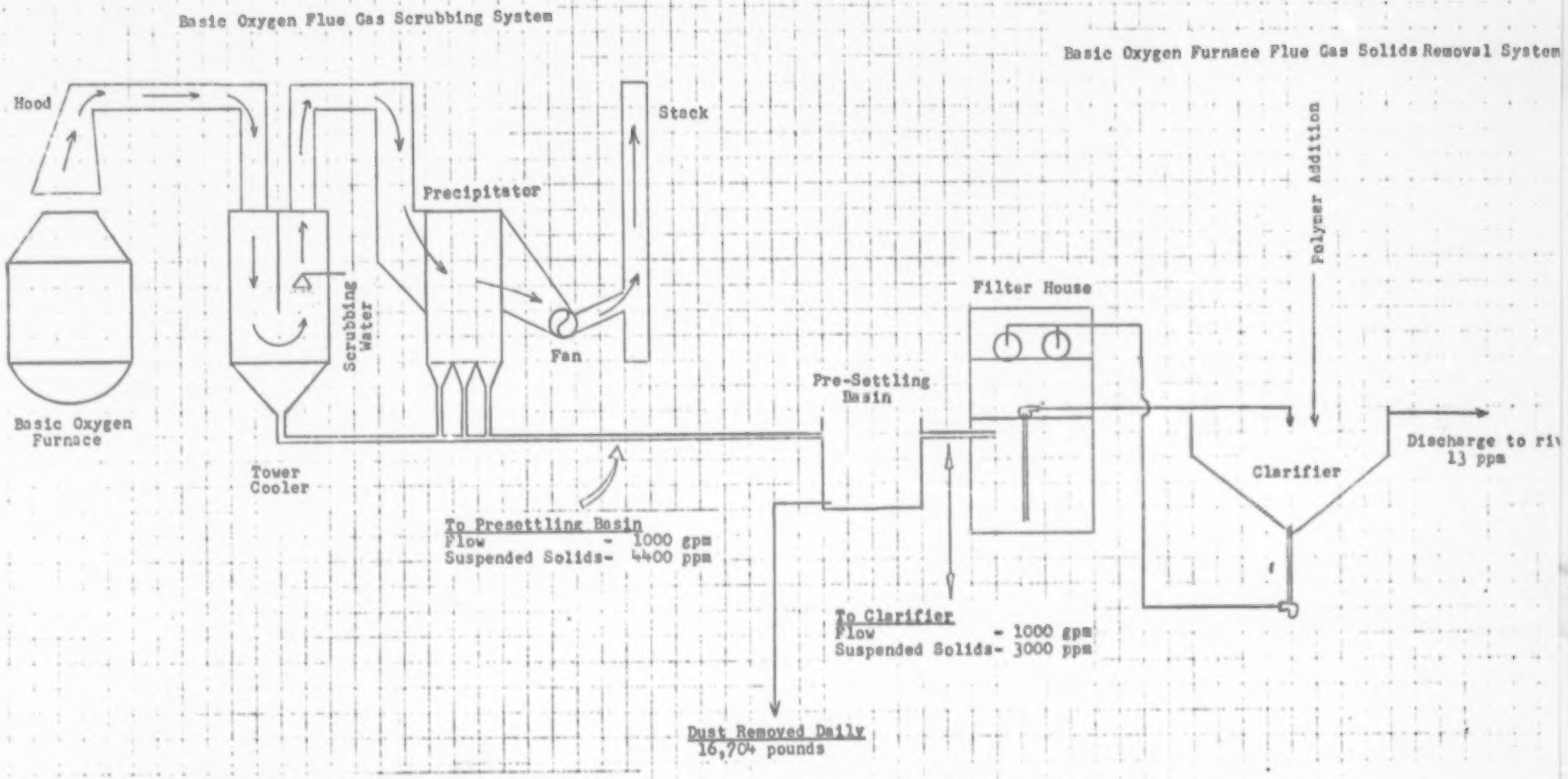
SCHEMATIC DIAGRAM OF POLYMER AND MAGNETIC FLOCCULATION OF BASIC OXYGEN FURNACE WASTEWATER

Figure 22



SCHEMATIC DIAGRAM OF INTERLAKE STEEL CORPORATIONS INTEGRATED AIR-WATER WASTE TREATMENT SYSTEM FOR THE BASIC OXYGEN FURNACE SHOP

Figure 23



Source: Krikau, F.G. " Effective Solids Removal of Basic Oxygen Furnace Flue Dust For Pollution Control ", Proceedings of the American Power Conference, 1966.

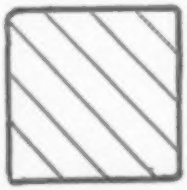
Hot Rolling Mills

Hot rolling mills are the major method by which ingot steel is transformed into finished products. Although hot rolling mills exist in such variety that simple classification and description is difficult, they may be divided into two parts whose end products are either semi-finished or finished.

Primary Mills - Semi-finished Products

In general, primary mills reduce hot ingots into blooms, billets or slabs which are defined as semi-finished products. While it is not possible to apply a precise definition to the term bloom, billet or slab, the following general characteristics normally relate to such terms.

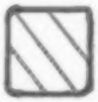
Bloom



Square or slightly oblong

Generally in the range 6" x 6" to 12" x 12" or with the cross section area measuring more than 36 sq. in.

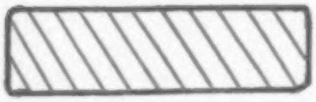
Billet



Mostly square

Generally in the range of 2" x 2" to 5" x 5"

Slab



Always oblong

Generally 2 to 9 inches thick and 24 to 60 inches wide

The basic operation in a primary mill is the gradual compression of the steel ingot between the surfaces of two rotating rolls, and the progression of the ingot through the space between the rolls. The physical properties of the ingot prohibit making the total required deformation of the steel in one pass through the rolls, so a number of passes in sequence are always necessary. As the ingot enters the rolls, high pressure water jets remove surface scale. The ingot is passed back and forth between the horizontal and vertical rolls while manipulators turn the ingot from time to time so that it is well worked on all sides. When the desired shape has been achieved in the rolling operation, the end pieces or crops are removed by electric or hydraulic shears. The semi-finished pieces are stored or sent to reheating furnaces for subsequent rolling operatings.

It is possible, and often economical, to roll ingots directly through the bloom, slab or billet stages into more refined and even finished steel products in one mill in a continuous operation, frequently without any reheating. Large tonnages of standard rails, beams, and plates are produced regularly by this practice from ingots from medium to large size. Most of the ingot tonnage, however, is rolled into blooms, slabs, or billets in one mill following which they are cooled, stored, and eventually rolled in other mills or forged.

Reheating is necessary throughout the rolling operating whenever the temperature of the metal being worked falls below that necessary to retain the required plasticity. Reheating furnaces are of two general classes -- batch and continuous types. Batch furnaces are those in which the charged material remains in a fixed position on the hearth until heated to rolling temperature. Continuous furnaces are those in which the charged material moves through the furnace and is heated to rolling temperature as it progresses toward the exit. One unique type of reheating furnace is the rotary hearth type used frequently for heating rounds in tube mills and for heating short lengths of blooms or billets for forging. The rotary hearth type permits external walls and roof to remain stationary while the hearth section of the furnace revolves. Batch furnaces vary in size from those with hearths of only a few feet square to those 20 feet in depth by 50 feet long; some modern continuous furnaces have hearths 80 to 90 feet long.

Secondary Mills - Finished Products

In advance of the finishing operations, the semi-finished products are inspected for surface defects which would affect the quality of the finished product. These surface defects may be removed by hand chipping, machine chipping, scarfing, grinding, milling, and hot steel scarfing. The various mechanical means of surface preparation are those common in all metal working and machine shop operations. Scarfing is a process of supplying streams of oxygen as jets to the surface of the steel product under treatment, while maintaining high surface temperatures that results in rapid oxidation and localized melting of a thin layer of the metal. The process may be a manual one consisting of the continuous motion of an oxyacetylene torch along the length of the piece undergoing treatment. In recent years the so-called hot scarfing machine has come into wide use. This is a production machine adapted to remove a thin layer (1/8 inch or less) of metal from all four sides of red hot steel billets, blooms, or slabs as they travel through the machine in a manner analogous to the motion through rolling mills. After this conditioning operation, the semi-finished products are heated in special reheating furnaces prior to rolling in highly specialized mills.

Sheet and Strip

The continuous hot-strp mill utilizes slabs which are brought to rolling temperatures in continuous reheating furnaces; the conditioned slabs pass through scale breakers and high pressure water sprays which dislodge the loosened scale. A series of roughing stands and a rotary crop shear produce a section that can be finished to a coil of the proper weight and gauge. The second scale breaker and high pressure water sprays precede the finishing stand train in which the final size reductions are made. Cooling water is applied through sprays on the run out table, and the finished strip is coiled. Such a mill can turn a thick 6 foot slab of steel into a thin strip or sheet a quarter of a mile long in 3 minutes or less. The modern hotstrip mill produces a product which may be up to 96 inches wide, although the most common width in newer mills is 80 inches. The product of the hot-strip mill may be sold as produced, or used within the mill for further processing in cold reduction mills, and for tin-plated or galvanized products. Historically, the terms "strip" and "sheet" as applied to the finished products, had reference to width and gage limitations, however these previous distinctions are not valid when applied to a continuous hot rolling mill. Thus all such rolling mills, whether the end product be strip, sheet or breakdown are referred to as "strip mills". During 1971 shipment of hot rolled sheet and strip products amounted to 34,095,289 tons of carbon grade, 1,010,626 tons alloy grade, and 467,812 tons of stainless for a total of 35,573,727 tons or 40.8% of total shipments. Hot strip mill capacity in the United States is estimated at over 88,000,000 tons annually.

Bar Products

Merchant-bar, rod, and wire mills produce a wide variety of products in continuous operations ranging from shapes of small size through bars and rods. The designations of the various mills as well as the classification of their products are not very well defined within the industry; in general, the small cross-sectional area and very long lengths distinguish the products of these mills. Raw materials for these mills are reheated billets. Many older mills use hand looping operations in which the material is passed from mill stand to mill stand by hand; newer mills use mechanical methods of transferring the material from stand to stand. As with other rolling operations, the billet is progressively squeezed and shaped to the desired product dimensions in a series of rolls.

Water sprays are used throughout the operation to remove scale. In 1971, shipments of bar products amounted to 11,810,708 tons of carbon grade, 2,237,892 of alloy grade, and 107,625 tons of stainless for a total of 14,156,225 tons or 16.2% of total shipments. Wire production totalled 2,791,343 tons or 3.2% of total shipments.

Plate Mills

Plates are classified, by definition, according to certain size limitations to distinguish them from sheet, strip, and flat bars. According to this classification plates are generally considered to be those flat hot-rolled finished products that are more than 8 inches wide and generally 1/4 inch or more thick. Sequence of operations for plate mills is heating of slabs, descaling, rolling, leveling, cooling, and shearing. Most plate mills use continuous type heating furnaces. Descaling in modern plate mills is accomplished by hydraulic sprays impinging on both top and bottom surfaces and operated at pressures up to 1500 pounds per square inch. Temperature variation in the plate from the front to the back is a problem of particular importance in rolling plates as is the care that must be exercised in cooling the rolled product so as to avoid distortion. Plate rolling mills are generally considered in two very broad design classifications. One type includes the universal mills which are characterized by vertical rolls preceding and following the horizontal rolls; such a mill produces a product of the width which conforms to narrow tolerances. The second general type of mill is the sheared plate mill which may or may not include edge working equipment. In 1971, shipment of plates amounted to 6,629,968 tons of carbon grade, 1,258,628 tons of alloy grade, and 50,828 tons of stainless for a total of 7,939,424 tons or 9.1% of total shipments.

Structural Shapes

A wide variety of various steel shapes are rolled from blooms; these shapes include structural sections such as I-beams, channels, angles wide flanged beams, H-beams, sheet piling, rails, and numerous special sections. The heating of the bloom for large sections is usually done in the batch type furnace, although some newer mills use continuous furnaces. A typical mill consists of a two high reversing breakdown stand in which initial shaping is accomplished followed by a group of three roll stands in train where the rolling process is completed; these mills are known as roughing stands, intermediate stands, and finishing stands. Several passes of the material is made back and forth through the breakdown roughing and intermediate mills; a single pass is usually made through the finishing stand. The sequence of operations then consists of heating bloom, rolling to proper contour dimensions, cutting while hot to lengths that can be handled, cooling to atmospheric temperature, straightening cutting to ordered lengths, and shipping. Shipment of shapes and rails in 1971 was 7,229,890 tons, of which 6,690,081 tons was carbon grade, 539,633 tons was alloy and 176 tons stainless. The total tonnage represents 8.3% of total shipment for 1971.

Pipe and Tubing

Welded tubular products are made from hot-rolled skelp with square or slightly beveled edges, the width and thickness of the skelp being selected to suit the various sizes to be made. The coiled skelp is uncoiled, heated, and fed through forming and welding rolls where the edges are pressed together at high temperature to form a weld. Welded pipe or tube can also be made by the electric weld process, where the weld is made by either fusion or resistence welding.

Seamless tubular products are made by rotary piercing of a solid round bar or billet followed by various forming operations to produce the required size and wall thickness. Pipe and tubing shipments for 1971 totalled 7,573,923 tons or 8.7% of total shipments, of the total, 6,438,617 tons was carbon grade, 1,108,599 was alloy grade and 26,707 was stainless.

Table XXI shows the net shipment of steel products by grade for the period 1962 to 1971. Although the total shipments increased from 70,552,000 ton in 1962 to a high of 93,877,000 tons in 1969, the percentage of each major grade remained relatively constant. For the entire period carbon steel shipments averaged 91.1%, alloy - 8.0% and stainless - 0.9%. In Table XXII the raw steel production is compared to the net shipment of steel products during the same ten year period. As indicated in the alloy and stainless steel grades, net shipments of semi-finished and finished products represent only 56-57% of the raw steel production, while in the carbon grades net shipments are 70.3% of raw steel production. Table XXIII shows all steel shipments during 1971 by grade and product.

Table XXI

NET SHIPMENTS OF STEEL PRODUCTS - 1962-1971

(thousands of net tons)

Year	Carbon	%	Alloy	%	Stainless	%	Total
1971	79,306	91.1	7,014	8.1	718	0.8	87,038
1970	83,145	91.6	6,944	7.6	709	0.8	90,798
1969	85,106	90.6	7,861	8.4	910	1.0	93,877
1968	83,221	90.6	7,816	8.5	819	0.9	91,856
1967	76,042	90.6	7,018	8.4	837	1.0	83,897
1966	81,089	90.1	7,973	8.9	933	1.0	89,995
1965	84,118	90.8	7,669	8.3	879	0.9	92,666
1964	77,608	91.4	6,566	7.7	771	0.9	84,945
1963	69,510	92.0	5,386	7.1	659	0.9	75,555
1962	65,077	92.2	4,843	6.9	632	0.9	70,552

Source: 1971 Annual Statistical Report of the American Iron and Steel Institute

Table XXII

RAW STEEL PRODUCTION VS. NET SHIPMENTS OF STEEL PRODUCTS - 1962-1971
(thousands of tons)

	Carbon			Alloy			Stainless		
Year	Production/Shipments	Diff.	%	Production/Shipments	Diff.	%	Production/Shipments	Diff.	
1971	107,700/79,306	28,394	73.6	12,173/7,014	5,159	57.6	1,263/718	545	56.
1970	117,411/83,145	34,266	70.8	12,824/6,944	5,880	54.1	1,279/709	570	55.
1969	124,832/85,106	39,726	68.1	14,861/7,861	7,000	52.8	1,569/910	659	57.
1968	116,269/83,221	33,048	71.5	13,761/7,816	5,945	56.7	1,432/819	613	57.
1967	113,190/76,042	37,148	67.1	12,572/7,018	5,554	55.8	1,451/837	614	57.
1966	118,732/81,089	37,643	68.2	13,718/7,973	5,745	58.1	1,651/933	718	56.
1965	116,651/84,118	32,533	72.1	13,318/7,669	5,649	57.5	1,493/879	614	58.
1965	114,442/77,608	36,834	67.8	11,191/6,566	4,625	58.6	1,433/771	662	53.
1963	98,714/69,510	29,204	70.4	9,343/5,386	3,957	57.6	1,204/659	545	54.
1962	89,160/65,077	24,083	72.9	8,083/4,843	3,240	59.9	1,085/632	453	58.
	Average		70.3			56.9			56.

TABLE XXIII
SHIPMENTS OF STEEL PRODUCTS BY GRADE - 1971

STEEL PRODUCTS	CARBON		ALLOY		STAINLESS		TOTAL	
	Net Tons	%	Net Tons	%	Net Tons	%	Net Tons	%
Ingot and Steel Casting	182,745	0.2	212,219	3.0	16,639	2.3	411,603	0.5
Blooms, Slabs, Billets, Sheer Bar	2,334,100	3.0	588,351	8.4	20,038	2.8	2,942,489	3.4
Skelp	20,803						20,803	
Wire Rods	1,539,230	1.9	37,820	0.6	10,136	1.4	1,587,186	1.8
Total Semi-Finished	4,076,878	5.1	838,390	12.0	46,813	6.5	4,962,081	5.7
Structural Shapes (heavy)	4,717,739	5.9	503,734	7.2	176		5,221,649	6.0
Steel Piling	410,100	0.5	34,551	0.5			444,651	0.5
Plates	6,629,968	8.4	1,258,628	17.9	50,828	7.1	7,939,424	9.1
Total Shapes and Plates	11,757,807	14.8	1,796,913	25.6	51,004	7.1	13,605,724	15.6
Rails-Standard (over 60 lbs.)	878,698	1.1					878,698	1.0
Rails - All Others	40,504	0.1					40,504	
Joint Bars	20,143						20,143	
Tie Plates	178,176	0.2					178,176	0.2
Track Spikes	76,996	0.1					76,996	0.1
Wheels (Rolled and Forged)	221,245	0.3	1,345				222,590	0.3
Axles	145,910	0.2	3				145,913	0.2
Total Rails and Accessories	1,562,242	2.0	1,348				1,563,590	1.8
Bars - Hot Rolled	5,548,100	7.0	1,971,043	28.1	42,139	5.9	7,561,282	8.7
Bar-Size Light Shapes	618,097	0.8					618,097	0.7
Bars - Reinforcing	4,516,916	5.7	4,410	0.1			4,521,326	5.2
Bars - Cold Finishing	1,127,595	1.4	184,429	2.6	65,486	9.1	1,377,510	1.6
Tool Steel			78,010	1.1			78,010	0.1
Total Bars and Tool Steel	11,810,708	14.9	2,237,892	31.9	107,625	15.0	14,156,225	16.3
Pipe and Tubing								
Standard	2,437,513	3.1	3,059				2,440,572	2.8
Oil Country Goods	1,033,838	1.3	370,235	5.3			1,404,073	1.6
Line	1,655,832	2.1	341,995	4.9			1,997,827	1.6
Mechanical	689,190	0.8	347,389	5.0			1,036,579	1.2
Pressure	153,921	0.2	44,698	0.6			198,619	0.2
Structural	468,323	0.6	1,223				569,546	0.6
Stainless					26,707	3.7	26,707	
Total Pipe and Tubing	6,438,617	8.1	1,108,599	15.8	26,707	3.7	7,573,923	8.7

183

Table XXIII
(Continued)

STEEL PRODUCTS	CARBON		ALLOY		STAINLESS		TOTAL	
	Net Tons	%	Net Tons	%	Net Tons	%	Net Tons	%
Wire - Drawn	2,094,535	2.7	3,059				2,132,479	2.5
Wire - Nails and Staples	339,634	0.4					339,634	0.4
Wire - Barbed and Twisted	97,677	0.1					97,677	0.1
Wire - Woven Fence	117,266	0.2					117,266	0.1
Baling Ties and Baling Wire	104,287	0.1					104,287	0.1
Total Wire and Wire Products	2,753,399	3.5	19,787	0.3	18,157	2.5	2,791,343	3.2
Black Plate	659,441	0.8					659,441	0.7
Tin Plate	5,121,197	6.5					5,121,197	5.9
Tin Free Steel	953,471	1.2					953,471	1.1
All Other T.M.P.	77,050	0.1					77,050	0.1
Total Tin Mill Products	6,811,159	8.6					6,811,159	7.8
Sheets - Hot Rolled	11,413,294	14.4	328,191	4.7	18,268	2.5	11,759,753	13.5
Sheets - Cold Rolled	14,678,818	18.5	32,954	0.5	186,557	26.0	14,898,329	17.1
Sheets & Strips - Hot Dip Galv.	4,737,786	6.0	4,707				4,742,493	5.5
Sheets & Strips - Electrolytic Galv.	325,115	0.4					325,115	0.4
All Other Metallic Coated	620,973	0.8	21				620,994	0.7
Electrical	79,313	0.1	560,445	8.0			639,758	0.7
Strip - Hot Rolled	1,359,796	1.7	55,701	0.8	20,508	2.9	1,436,005	1.7
Strip - Cold Rolled	880,194	1.1	28,601	0.4	242,479	33.8	1,151,280	1.3
Total Sheets and Strip	34,095,289	43.0	1,010,626	14.4	467,812	65.2	35,573,727	40.9
Total Net Shipments	79,306,099	100.0	7,013,555	100.0	718,118	100.0	87,037,772	100.0
Shipments to Reporting Co.	3,708,210		146,427		9,325		3,863,962	
Total Gross Shipments	83,014,309		7,159,982		727,443		90,901,734	

Source: 1971 Annual Statistical Report of the American Iron and Steel Institute

Waste Loads from Hot-Rolling Operations

The waterborne wastes from hot-rolling operations consist primarily of suspended solids and oil. The solids, of course, are the scale particles which are removed from the hot steel by mechanical action and water sprays. The oil originates from that used to lubricate the machinery, and varies particularly with the age and condition of the mill. The quantities of scale vary with the surface condition of the steel at the time of rolling, the type of steel, the stage of finishing, and the type of product.

In general, the scale loss of carbon steel is about 3% and that of stainless steel about 1%. The various grades of alloy steel have scale losses intermediate between these valves, probably averaging 2%. Much of this scale is in the form of large particles and drops out in even the most crude scale pit of the type long used to guard against sewer clogging with no thought of pollution abatement. The only way to measure the gross amount of scale with any accuracy at all is to weigh the scale recovered over a period of time. The resulting number, i.e., 20,40, or 60 pounds per ton has little significance insofar as potential pollution is concerned. The gross amount of potential effluent oil can likewise only be determined by the oil consumption in a mill over a period of time. The oil, however, all constitutes potential pollution in the absence of any recovery method.

Although rolling oil lubricants are normally associated with cold rolling operations, recent developments in high temperature rolling oils have precipitated experimentation of their use on hot mills. Since January,1969 the Sharon Steel Corp's. plant at Farrell has used rolling lubricants on approximately 85% of the products rolled on the 60 in. semicontinuous hot strip mill. Experimentation between July, 1968 and January, 1969 at the Farrell hot strip mill showed the following benefits: increased roll life, decreased amount of roll grinding, decreased total roll cost, increased production, decreased labor costs, decreased pickling costs, and an improved product. These developments indicate a possible future for hot rolling mill oils and thus an additional pollution parameter for such operations.

The U.S.G.S. data on hot-rolling mills give the following gross water uses:

Primary Mills (gallons per semi-finished ton)

Median	2,070
Average	3,570
Maximum	11,300
Minimum	637

Secondary Mills (gallons per finished ton)

Median	7,640
Average	11,700
Maximum	37,300
Minimum	2,780

It is very difficult to sample a rolling mill effluent, i.e., the scale pit influent and arrive at any sort of consistent concentration by analyzing the entire sample for either suspended solids or oil. As has been pointed out, the result means little in terms of potential pollution load. Most steel industry people have accepted the Sedimentation Index concept for designing sedimentation basins; the method of sampling and analysis is an integral part of the procedure.

A sample is taken and the solids and oil remaining in suspension after varying periods of time in a standardized test procedure are determined. If the empirical procedure is followed precisely, the time period allowed for sedimentation (flotation in the case of oil) can be related to the performance of a basin which is characterized by a Sedimentation Index (S.I.) numerically equivalent to that time period in minutes.

A crude scale pit suitable only to prevent sewer clogging will have an S.I. of 0.1 minutes or less. The best scale pit will usually have an S.I. of about 1.0 minutes, ranging up to possibly 10 minutes for large pits with relatively lower flow rates, or for circular clarifiers.

The data of Table XXIV show water use rates for a variety of hot-rolling mills. In Table XXV data are compared for water uses as given in the 1968 Profile, the NUS report, the examples of Table , and the U.S.G.S. report. The NUS data apparently refer only to process water, and apparently do not include water used on strip mill runout tables.

The best estimates on the basis of the data of Table XXV, weighting the NUS report data for an average sample size of 6, and considering that process changes, since the 1968 profile study generally tend to increase gross water use, are summarized in Table XXVI

Table XXIV

WATER USE RATES REPORTED FOR SPECIFIC ROLLING MILLS

Type of Mill	Production Tons/day	Water Use, gallons per ton				
		Process	Reheat	Roughing	Finishing	Total
Hot-Strip Mill	8,400	-	686	2,923	1,029(2)	-
Hot-Strip Mill	1,410	10,213	-	-	-	-
Hot-Strip Mill	8,630	10,012	2,503	-	-	12,515
Hot-Strip Mill	9,493	9,101	3,034	-	-	12,135
Hot-Strip Mill	12,715	13,590	4,530	9,060	4,530	18,120
Hot-Strip Mill	1,726	-	-	-	8,201	-
Hot-Strip Mill	9,205	15,644	6,257	-	-	21,901
Hot-Strip Mill	8,055	16,447	5,363	-	-	21,810
Hot-Strip Mill	7,249	7,151	-	-	-	-
Plate Mill	2,164	5,989(1)	-	-	-	-
Plate Mill	3,279	10,540	6,587	-	-	-
Slab Mill and Scarfing	11,507	1,502	-	-	-	-
Bar Mill	523	9,474	-	-	-	-
Blooming Mill	2,589	1,785	-	-	-	-
Blooming Mill	8,493	1,187	-	-	-	-
Slab Mill	1,726	3,354	-	-	-	-
Rod and Bar Mill	2,742	788	188	-	-	-

(1) effluent, 50% recycled
(2) does not include runout tables

Table XXV

WATER USES IN HOT-ROLLING MILLS (GALS. PER TON OF ROLLED PRODUCTS)

	Process Water	Furnace Cooling	Total	Data Source
Hot-Strip Mills	11,737	3,729	17,296	Table 1
Hot-Strip Mills	6,300	-	-	NUS Report
Hot-Strip Mills	6,000	-	-	1968 Profile
Plate Mill	11,259	6,587	-	Table 1
Plate Mill	13,000	-	-	NUS Report
Bar Mill	9,474	-	-	Table 1
Bar Mill	7,500	-	-	NUS Report
Bar Mill	7,000	-	-	1968 Profile
Blooming Mill	1,486	-	-	Table 1
Blooming Mill	1,200	-	-	NUS Report
Blooming Mill	2,300	-	-	1968 Profile
Slab Mill	3,354	-	-	Table 1
Slab Mill	1,200	-	-	NUS Report
Slab Mill	720	-	-	1968 Profile
Structural Mill	2,000	-	-	NUS Report
Rod Mill	3,000	-	-	NUS Report
Seamless Pipe Mill	5,000	-	-	NUS Report
Billet Mill	2,000	-	-	NUS Report
Billet Mill	1,400	-	-	1968 Profile

Table XXVI

SUMMARY OF HOT-ROLLING WATER USES

(Process Water - Gals. Per Ton Rolled Products)

Hot-Strip Mills	11,000
Plate Mills	13,000
Bar Mills	9,000
Blooming Mills	1,500
Slab Mills	1,500
Structural Mills	2,000
Rod Mills	3,000
Seamless Pipe Mills	5,000
Billet Mills	2,000

The water use in an integrated mill can be approximated by the weighted average use per shipments of the various types of carbon steel products for 1971.

Steel Products	Shipments, tons
Blooming Mills: (107,700,000 - 11,000,000) (ingot tons less continuous casting)	96,700,000
Structural Mills (plus rails & accessories)	6,690,081
Plates	6,629,968
Rod Mills (wire and wire rods)	4,292,629
Bar Mills	11,810,708
Pipe and Tubing	6,438,617
Billet Mills (wire plus bars plus tube and pipes)	22,541,954
Slab Mills (plate plus strip mills)	47,536,416
Strip Mills (sheets plus tinplate and black plate)	40,906,448
Total - Finished and Semi-Finished	243,547,000

Rolling Mill Type	Process Water Use	% of Rolling	Weighted Use	% Water Use
Hot-Strip Mills	11,000	16.8	1,848	46.7
Plate Mills	13,000	2.7	351	8.9
Bar Mills	9,000	4.8	432	11.0
Blooming Mills	1,500	39.7	596	15.1
Slab Mills	1,500	19.6	294	7.5
Structural Mills	2,000	2.7	54	1.4
Rod Mills	3,000	1.8	54	1.4
Pipe Mills	5,000	2.6	130	3.3
Billet Mills	2,000	9.3	186	4.7
			3,945	

Water use per finished ton $= \left(\frac{243.547}{79.306}\right) \times 3945 = 12{,}115$ gals./ton

The total average water use of 15,270 gals. per finished ton as shown by the U.S.G.S. data, considered with the above, indicates a cooling water use of 3,155 gals. per finished ton. This is very close to the median indicated in Table and a weighted average of the mills listed and probably indicates a reasonable value.

The indicated wastewater volume of 3,945 gals. per ton rolled agrees well with the 1967 Profile estimates of 3,160 gals. per ton rolled in typical production technology and 4,268 gals. per ton rolled in advanced technology.

The raw waste loads on the basis of sampled rolling mills effluents, i.e., prior to scale pits, may be approximated from the NUS report concentrations, the flows of Table XXVI, and the percentage water uses by mill previously calculated, the total use being 12,115 gals. per ton of finished steel.

Type of Mill	Wastewater gal. per ton	Concentration, ppm S.S.	Oil	Load,#/ton S.S.	Oil
Hot-Strip Mills	5,657	575	40	27.1	1.88
Plate Mills	1,078	185	45	1.66	0.40
Bar Mills	1,333	200	15	2.22	0.17
Blooming Mills	1,829	1,000	10	15.2	0.46
Slab Mills	909	2,000	30	15.1	0.23
Structural Mills	170	900	200	1.27	0.28
Rod Mills	170	120	30	0.17	0.04
Pipe Mills	400	840	7	2.80	0.02
Billet Mills	569	480	55	2.28	0.26
			Totals	67.8	3.74

The raw waste load of suspended solids is very close to the generally accepted scale loss of 3% and that of oil agrees with the value of the NUS report, arrived at by an entirely different calculation. Expressed in average contrations for all hot-rolling:

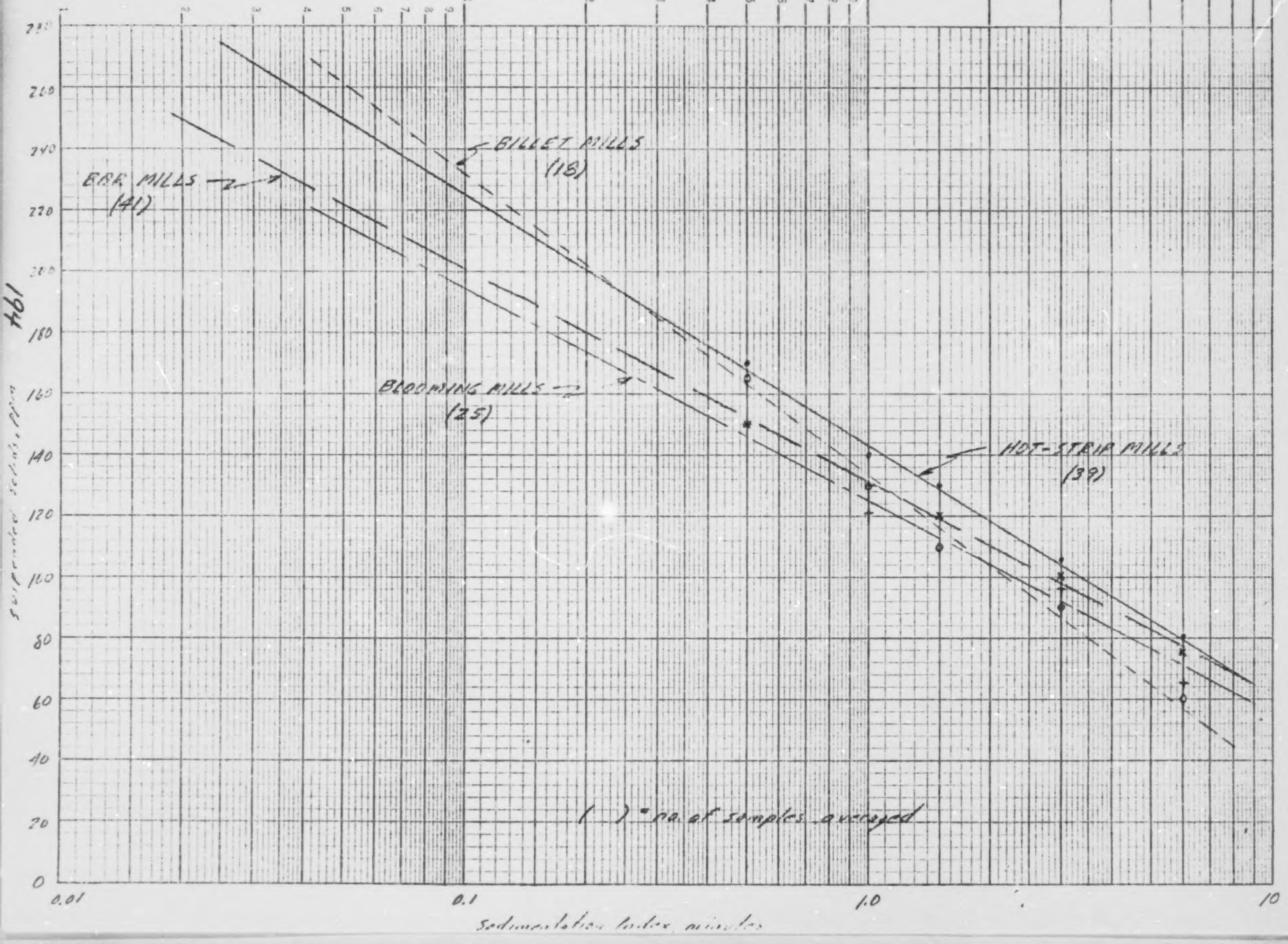
suspended solids = 672 ppm
oil = 37 ppm

The data of Figure 24 show settling rate curves, determined by the S.I. procedure, for 123 samples of various rolling mill effluents. It is apparent that for the purposes here an average can be used to define levels of treatment. A crude scale pit can thus be expected to have an effluent of about 215 ppm, a fairly good scale pit about 130 ppm, and the best plain secondary settling basin about 50 ppm. Oil in the effluents of the former two would be about equal to the raw waste load (37 ppm) and from the latter about 15 ppm, assuming efficient oil skimming.

Properly designed and operated deep bed filters produce an effluent of 15 ppm or less suspended solids and 5 ppm oil. Recycling

K•E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

Figure 24 Sedimentation Index Curves



of the treated effluent with 5% blowdown is readily achievable. This level of treatment would thus give waste loads as follows:

$$\text{suspended solids} = 12{,}115 \times 8.33 \times 10^{-6} \times 15 \times 0.05 = 0.08\#/\text{ton}$$

$$\text{oil} = 12{,}115 \times 8.33 \times 10^{-6} \times 5 \times 0.05 = 0.03\#/\text{ton}$$

The waste loads from hot-rolling operations at various levels of treatment may be summarized as below:

Standard Raw Waste Load:
  Suspended solids and oil in mill effluent
Base Level of Treatment:
  Scale pit with S.I. = 0.1 minutes
Present Practice:
  Scale pit with S.I. = 1.0 minutes
Best Practicable Treatment:
  Scale pit + deep-bed filters, once-through use
Best Available Treatment:
  Scale pit + deep-bed filters, 5% blowdown

Level of Treatment	Volume gal./ton	Suspended Solids #/ton	Oil #/ton
Standard Raw Waste	12,115	67.8	3.74
Base Level	12,115	21.7	3.74
Present Practice	12,115	13.1	3.74
Best Practicable	12,115	1.51	0.50
Best Available	606	0.08	0.03

MINI-STEEL PLANT

With a combined raw steel capacity now in excess of 7,000,000 tons annually, the so-called mini-steel plant or neighborhood steel plant has become a significant part of the steel industry. Production per plant ranges from 50,000 up to 400,000 tons annually and usually serves a marketing area within 250 miles of the plant. Since the electric furnace has become an economical producer of carbon steels and the successful application of continuous casting of billets, the last ten years have produced an unprecedented growth of such plants. Capitalization per annual ton produced amounts to about $100 for the mini-plant, compared to about $500 for a completely integrated large townage facility. This modern plant is generally a semi-integrated operation, employing electric furnaces, continuous casting, reheat furnaces and rolling facilities. Since the majority of these plants are relatively new, they generally contain up-to-date pollution control systems. Usually, process water for the plant is from a closed system with only slight discharges.

Table XXVII tabulates the production statistics for most mini-steel plants. In Table XXVIII the water and air pollution control systems at 24 of these plants are described.

Table XXVII Steelmaking, Casting, Rolling Capacity at Mini-Steel Plants

Company &	Plant Location	Products	No. of Arc Furnaces	Annual Raw Steel Capacity, Tons	Annual Casting Capacity, Tons	Annual Rolling Capacity, Tons
Allison Steel Mfg Co.	Tempe, Ariz	Bars, rounds	3	180,000	NONE	180,000
Ameron Steel Corp	Etiwanda, Calif	Rod, Bars, Wire	3	160,000	150,000	150,000
Armco Steel Corp	Sand Springs, Okla	Rebars & Fence Posts	2	180,000	350,000	145,000
Border Steel Mills, Inc.	Vinton, Texas	Rebars, Angles, Rounds	2	140,000	130,000	120,000
Calumet Steel	Chicago Hts, Ill.	Bars, Structural Shapes	2	180,000	250,000	215,000
Franklin Steel	Franklin, Pa.	Bars, Structural	NONE	70,000	NONE	70,000
Ingersoll Steel	New Castle, Ind.	Plate, sheet, strip	4	- -	60,000	70,000
Cascade Steel Rolling Mills	McMinnville, Ore.	Bars	2	100,000	130,000	130,000
Lemont Mfg Corp.	Lemont, Ill.	Rebars, Shapes, Rounds	3	225,000	NONE	220,000
Milton Mfg. Co.	Milton, Pa	Rebars, Rounds	3	170,000	None	170,000
Southern Electric Steel	Birmingham, Ala	Rebars, Rounds, Angles	2	90,000	NONE	146,000
Florida Steel Corp.	Croft, N.C.	Rebars, Rounds	2	100,000	NONE	100,000
Florida Steel Corp.	Indiantown, Fla	Rebars, Rounds, Angles	1	90,000	90,000	150,000
Florida Steel Corp.	Tampa, Fla.	Rebars, Rounds, Angles	3	200,000	160,000	160,000
Georgetown Steel Corp	Georgetown, S.C.	Bars, Rebars, Wire	2	300,000	300,000	300,000
Harrisburg Steel Co.	Harrisburg, Pa.	Ingots, Blooms, Billets	3 (open hearth)	125,000	NONE	125,000
Hawaiian Western Steel	Ewa, Hawaii	Ingots, Rebars	1	104,000	NONE	104,000
Intercoastal Steel Corp.	Chesapeake, Va	Rebars, Rounds, Angles	2	100,000	NONE	100,000
Jones & McKnight Corp.	Kankakee, Ill.	Rebars, Rounds	2	135,000	NONE	100,000
Judson Steel Corp.	Emeryville, Calif.	Rebars	1	160,000	NONE	100,000
Kentucky Electric Steel Co.	Coalton, Ky	Flats, angles	2	120,000	100,000	120,000
Knoxville Iron	Knoxville, Tenn.	Bars	3	100,000	100,000	90,000
Mississippi Steel	Flowood, Miss.	Rebars, shapes	2	60,000	NONE	90,000
New Jersey Steel	Sayreville, N.J.	Bars, rounds	1	140,000	n/a	140,000
North Star Steel Co.	St Paul, Minn.	Bars, Rebars, Structural	2	300,000	300,000	300,000
Northwest Steel Rolling Mills	Seattle, Wash	Ingots, billets, bars	2	—	None	500,000
Northwest Steel Rolling Mills	Kent, Wash	—	1	110,000	NONE	—
Eastern Carolina Steel	Darlington, S.C.	Bars, Angles	2	120,000	130,000	120,000
Oregon Steel Mills, Inc	Portland, Ore	Plates, Bars	4	400,000	500,000	350,000
Owen Electric Steel Co.	Cayce, S.C.	Ingots, Rebars	3	41,000	None	—
Pacific States Steel Corp	Union City, Calif.	Bars, Shapes, Ingots	4 (open hearth)	400,000	NONE	400,000

Pollak Steel Co.	Marion, Ohio	Rebars, Angles, Rounds	1	100,000	180,000	150,000
H.K. Porter Co.	Birmingham, Ala.	Rails, Bars, Plates	3	225,000	230,000	240,000
H K Porter Co.	Huntington, W.Va	Bars, Rails, Bolts	2	150,000	None	285,000
Roanoke Electric Steel Corp.	Roanoke, Va.	Ingots, Bars, Rebars	3	170,000	72,000	114,000
Roblin Industries, Inc.	N. Tonawanda, N.Y	Bars, Rod, Wire	None	—	None	125,000
Roblin Industries, Inc.	Dunkirk, N.Y.	—	2	160,000	100,000	None
Ross Steel Works	Amite, La.	Rebars	3	100,000	None	200,000
Soule Steel Co.	Long Beach, Calif.	Ingots, Bars, Shapes	2	165,000	160,000	100,000
Southwest Steel Rolling Mills	Los Angeles, Calif.	Rebars, Angles	2	185,000	None	120,000
Structural Metals, Inc.	Seguin, Tex.	Rebars	2	90,000	None	100,000
Tennessee Forging Steel	Harriman, Tenn	Rebars, Angles	2	150,000	110,000	120,000
Tennessee Forging Steel	Newport, Ark.	Rebars, Angles	1	160,000	85,000	N/A
Texas Steel Co.	Fort Worth, Tex	Rebars, Angles, Shapes	5	200,000	None	150,000
Washburn Wire Co.	Phillipsdale, R.I.	Bars, Wire, Strip	2	120,000	None	80,000

Table XXVIII

WATER AND AIR FACILITIES AT MINI-STEEL PLANTS

Company and Division	Water average/source	Waste water treatment	Air pollution control
Allison	Approximately 100 gpm/recycle system, make-up from deep wells.	Sanitary-septic tank. Closed seepage system for process water.	Baghouse and wet scrubbers.
Ameron	4,100,000 gal per month/ own well.	Process water recirculated. Oil removal from waste water.	Three baghouses, 200,000 cfm total fume processed, side draft hoods.
Border	Two wells at plant site.	Cesspools for sanitary water. Process water recirculated through cooling towers and recycle pond.	Fourth hole snorkel on electric furnaces to a baghouse.
Cascade	Recycle 4500 gpm/makeup from city of McMinnville plus run-off.	Process-cooling and settling pond. Recycling system. Sanitary discharge to municipal systems.	Bag filter w/spark trap-tempering air keeps fume at about 250°F.
Ceco-Lemont	5,000 gpm/waterway.	Filter tanks and settling basin.	Baghouse for each of three furnaces.
Ceco-Milton	53,000,000 gal per month/ White Deer Mountain Water Co.	Settling basin. Oil skimming. Cooling spray system, pH monitoring.	Baghouse (180,000cfm), 15 in.H_2O suction-type.
Ceco-Southern Electric	14,500,000 gal per month/ industrial Water Works, city of Birmingham.		
Florida-Croft	Plant water reservoir.		Direct evacuation baghouse.
Florida-Indiantown	Closed cycle-polishing pond, own well make-up.	Plant sewage treatment.	Direct evacuation baghouse (five compartment).
Florida-Tampa	Plant water reservoir.		Direct evacuation baghouse.
Georgetown	13,000 gpm/four closed circuit loops, five cooling towers.		Direct evacuation to wet precipitators.

Table XXVIII
(Continued)

Company and Division	Water average/source	Waste water treatment	Air pollution control
Intercoastal	530,000 gal per month/ makeup from own well, cooling ponds-recycled.	Sewage lagoon with chemical treatment.	Baghouse for shredder. Experimental smoke and dust controls on electric furnaces being installed.
Jones & McKnight-Kankakee	Recycle system.		Hood evacuation for electric furnaces to an eight-compartment baghouse.
Judson	Closed.	Sewered to municipal sewage disposal plant.	Snorkel on arc furnaces to electrostatic precipator. Canopy and baghouse being installed.
Kentucky Electric	4,000 gpm/closed cycle from pond.	Sewage treatment plant on site. Chlorination. Discharge to nearby stream.	Two baghouses.
North Star	18,000 gpm recycled/ 1500 gpm make-up from own well.	Sewage-process water-closed cycle; 100,000 gal per month aerated and chlorinated.	Twelve-compartment bag filter (360,000 cfm). Direct furnace evacuation and building evacuation from hoods above cranes.
Pollak	4,000,000 gal per month.		Baghouse.
Roblin-North Tonawanda	956,000 gal per month cooling pond.	City of North Tonawanda sewage system.	None required-all natural gas.
Roblin-Dunkirk	13,432,000 gal per month cooling towers	City of Dunkirk sewage system.	Arc furnaces-direct evacuation to a five-compartment baghouse. Billet grinding and shot blasting are equipped with dust collectors.

Table XXVIII
(Continued)

Company and Division	Water average/source	Waste water treatment	Air pollution control
Ross	Closed system, 4,000,000 gal pond-surface water make-up	To municipal sewage system.	Conventional.
Southwest	Closed system, all recycled from pond, city water make-up.	To municipal sewage system.	
Structural Metals			Baghouse for each furnace. Building evacuation system being installed (700hp).
Tennessee Forging-Harriman	3,000,000 gal per month.		Direct shell evacuation and baghouse.
Texas			Electric furnace dust control system to be installed.
			Ten-section baghouse for electric furnaces.

Source: Kotsch, J.A. "A Look At The Mini-Plants", Iron and Steel Engineer Year Book - 1971, pp. 411-428.

Costs of Wastewater Treatment Methods

The costs of plain sedimentation in a scale pit with an S.I. of 0.1 minutes are zero, particularly insofar as pollution control is concerned. The value of the recovered scale exceeds at least the operating cost, and the scale pit itself is constructed primarily to protect the sewer system.

A scale pit with an S.I. of one minute or more has usually been constructed with the objective of pollution control under past standards of performance which were not very stringent. The capital costs can be estimated as the difference between the lowest and highest unit costs reported in the 1967 Profile and updated to 1972 $:

$$(\$2.50 - \$1.11)(1.035)^{6} = \$1.71\text{/annual ingot ton}$$

or

$$\$1.71\left(\frac{107700}{79306}\right) = \$2.32\text{/annual finished ton}$$

Direct operating costs in 1966 $ were $0.023 per 1,000 gal. such costs are presently then:

$$\$0.023 \times 12.115 \times (1.035)^{6} = \$0.34\text{/ finished ton}$$

The costs of deepbed filters are $50/gpm and of flocculator-clarifiers about $40/gpm at the maximum. Costs as low as $20/gpm and $33.3/gpm ($1968) have been estimated for filters and flocculator-clarifiers respectively at 9,000 gpm (Lukens Steel Co.).

$12{,}115 \text{ gals.} \times 79{,}306{,}000 \text{ tons} = 960.792 \times 10^9 \text{ gals./year}$

$$\frac{12{,}115 \text{ gals./ton}}{365 \text{ days/yr.} \times 1440 \text{ minutes/day} \times 20/21 \text{ shifts}} = 0.0242 \text{ gpm/annual ton}$$

Deepbed filters = $0.0242 \times \$50 = \$1.21$/annual finished ton

Flocculator-clarifiers = $0.0242 \times \$40 = \$0.97$/annual finished ton

Direct costs for flocculation-sedimentation are as follows on the basis of the 1966 cost of $0.122 per 1,000 gals.:

$\$0.122 \times 12.115 \times (1.035)^6 = \$1.81$/annual finished ton

Operating labor for filters is about 1/3 of that for flocculation-sedimentation and chemical costs for the former are nil. (Lukens Steel Co.). The direct operating costs for filters are thus about 50% of those of flocculation-sedimentation or about $0.90/annual finished ton.

The 25,000 gpm filtration-recirculation system at Colorado Fuel and Iron (Pueblo, Colorado) cost $2 million, or $80 per gpm. That particular installation utilizes a gravity system which is significantly less expensive than a pressure system. The indicated costs of filtration and recirculation here are $40 per gpm for each. The operating costs are probably likewise equal, totaling about $1.80/annual finished ton.

Estimated costs are thus summarized as follows:

Treatment	Costs, $ per annual finished ton Capital cost,$	Direct Operating Costs,$/yr
Base Level (crude pit)	nil	nil
Present Practice (S.I. = 1.0)	1.71	0.34
Best Practicable (filters)	1.21	0.90
Best Available (recirculation)	1.21	0.90

ROLLING MILL FACILITIES AND DAILY CAPACITY

Table XXIX

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
Alan Wood	Ivy Rock	Pa.	3596			1404						1036
Allegheny Ludlum	Brakenridge	Pa.	2589									1726
Allegheny Ludlum	Dunkirk	N. Y.			cogging 201 29					29 158	2 - 86	
Allegheny Ludlum	New Hartford	N. Y.			1-no figures						1-no figures	
Allison Steel	Tempe	Ariz.	432				432					
AM Compressed Steel	Cinncinnati	Ohio					35					
Armco Steel	Ambridge	Pa.	1438				978 460					
Armco Steel	Ashland	Ky.	1438	5466								4890
Armco Steel	Butler	Pa.		2721								2632
Armco Steel	Zanesville	Ohio										158
Armco Steel	Houston	Texas	2445	4315	1323	1870 2445	863	949		719		
Armco Steel	Kansas City	Mo.	2387		2387					1150	374 1036	

Table XX/X

ROLLING MILL FACILITIES AND DAILY CAPACITY

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
Armco Steel	Middletown	Ohio		7479								8055
Armco Steel	Sand Springs	Okla									403	
Armco Steel	Baltimore	Md.	257				56,30 104			104		
Atlantic Steel	Atlanta	Ga.	1380		1380		391			863 460		161 143
Babcock&Wilcox Co.	Beaver Falls	Pa.	1438				403 575					
Baldwin-Lima-Hamilton Corp.	Burnham	Pa.	Wheel 190	Ring & Tire 121								
Bethlehem Steel	Bethlehem	Pa.	(comb) 2661 5063 3481 4027 1251		604		734 121 52 337	3106 1525 1007 575 690				
Bethlehem Steel	Steelton	Pa.	3812				805 1956	3337				
Bethlehem Steel	Williamsport	Pa.					575					
Bethlehem Steel	Sparrows Point	Md.	8371	8630 6674	2963 2992 898	2660 777	1102			1079		7853 7134

Table XXIX

ROLLING MILL FACILITIES AND DAILY CAPACITY

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
Bethlehem Steel	Lackawanna	N. Y.	4171 5293 5365	8975	3395		746 978 1251	2733 1539	2057			7249
Bethlehem Steel	Johnstown	Pa.	6962 Wheel 144 302		2229 2805	935 504	705 690 111 1122 268 66 29			863		
Bethlehem Steel	Burns Har.	Ind.		8055		3279						9493
Bethlehem Steel	South San Francisco	Calif.					224	388 604				
Bethlehem Steel	Los Angeles	Calif.	1942		1366		662			705		
Bethlehem Steel	Seattle	Wash.	1870			432	547					
Border Steel Rolling Mills, Inc.	Vinton	Texas					374					
Calumet Steel (Borg-Warner)	Chicago	Ill.					311 259 73					
Franklin Steel (Borg-Warner)	Venango	Pa.					201					
Ingersoll Steel (Borg-Warner)	New Castle	Ind.				46						144

ROLLING MILL FACILITIES AND DAILY CAPACITY

Table XXIX

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
Ingersoll Steel (Borg-Warner)	Chicago	Ill.				230						
Braeburn Alloy Steel	Braeburn	Pa.					9.2					
Carpenter Tech Corp	Reading	Pa.					144					127
Carpenter Tech Corp	Bridgeport	Conn	575				144					
CECO Corp.	Lemont	Ill.					690					
CECO Corp.	Milton	Pa.					374					
CECO Corp(Southern Elect Steel Div)	Birmingham	Ala.					426					
C F & I Steel	Pueblo	Colo	1786				316 452 158	699	2589	1064		
C F & I Steel	Roebling	N. J	633							547		35
Columbia Tool Steel	Chicago	Ill.					5					
Continental Steel	Kokomo	Ind.	1381		1381					863		
Copperweld Steel Co	Warren	Ohio	1525				552				690	
Copperweld Steel Co	Glassport	Pa.								158		

Table XXIX

ROLLING MILL FACILITIES AND DAILY CAPACITY

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
Crucible Inc.	Midland (Alloy Div.)	Pa.	3236		1841		1294				460	
Crucible Inc.	Midland (S.S. Div.)	Pa.	Appear all to be cold mills.									
Crucible Inc.	Syracuse	N. Y.			187		60 26	26		66 124		
Cyclops Corp. (Empire-Reeves Div.)	Mansfield	Ohio										N. A.
Cyclops Corp.	Bridgeville	Pa.	99		16		14 19			22		58
Cyclops Corps. (UN.-Cyclops S.S. Div.)	Pittsburgh	Pa.		29								29
Cyclops Corps.	Titusville	Pa.					8.6 15 22					
Detroit Steel Corp	Portsmouth	Ohio	3740		1208 (Billet & Bar)					575		3452
Eastern Stainless Steel Co.	Baltimore	Md.		115								104 (Sheet & Plate)
Edgewater Corp.	Oakmont	Pa.						81 (small rings)	201 (Wheels Tires Rings)			

502

Table XXIX

ROLLING MILL FACILITIES AND DAILY CAPACITY

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
Etiwanda Steel Producers	Etiwanda	Calif					288					
Florida Steel Corp	Tampa	Flo.					460					
Florida Steel Corp	Croft	N.C.					288					
Ford Motor Co.	Dearborn	Mich.	5638 2848	11507			575					5710
Granite City Steel	Granite City	Ill.		6041								N.A.
H.M. Harper, Co.	Morton Grove	Ill.	35									
Harrisburg Steel Co	Harrisburg	Pa.	360									
Hawaiian Western Steel Limited	Ewa	Hawaii					299					
Inland Steel Co.	East Chicago	Ind.	1036 3165 2589 6760	11507	1726 446	935	777 863 1366 921	1726				3738 4890 9205
Intercoastal Steel Corp.	Northampton,	Va.			288		288					
Interlake, Inc.	Chicago	Ill.	1913		1668							1410 331 489

Table XXIX

ROLLING MILL FACILITIES AND DAILY CAPACITY

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
Interlake, Inc.	Wilder,	Ky.										1200
I-H, Wisc. Steel Division	South Chicago	Ill.	2589			777 (Bar & Plate)	690 690					
Jersey Shore Steel Co.	South Avis	Pa.					144					
Jessop Steel Co.	Washington	Pa.	181 (Slab &Bloom & Plate)				19					18 4.3
Jessop Steel Co. (Green River Steel Div.)	Owensboro	Ky.	345 (Bloom & Bar)									
Jones & Laughlin Steel Corp.	Aliquippa	Pa.	6628		2209		1621(Rounds) 994			1139		4867
Jones & Laughlin	Pittsburgh	Pa.	5896 3306		2244 1036		1174 932					2877
Jones & Laughlin	Cleveland	Ohio		8035								8802
Jones & Laughlin (Stainless Div.)	Warren	Mich.	690				323 72					

Table XXIX

ROLLING MILL FACILITIES AND DAILY CAPACITY

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
Joslyn Stainless	Fort Wayne	Ind.	288				69 46					
Judson Steel Corp.	Emeryville	Calif.					230 201					
Kaiser Steel Corp.	Fontana	Calif.	3590	8975		2422		1315			958	4315
Kentucky Elec. Steel Co.	Coalton	Ky.					403	403				
Keystone Steel & Wire	Peoria	Ill.	1496				1007			935		
Laclede Steel Co.	Alton	Ill.	1582				496			475		
Laclede Steel Co.	Madison	Ill.					575					
Latrobe Steel Co.	Latrobe	Pa.	G - NOT DESCRIBED									
LeTourneau, Inc.	Longview	Tex.		748								
Lone Star Steel Co.	Lonestar	Tex.		3441			173					2693
Lukens Steel Co.	Coatesville	Pa.				618 1654						
McLouth Steel Corp.	Trenton	Mich.	6904	6904 (Universal)								6904
Mississippi Steel Div. (Magna Corp.)	Flowood	Miss.					129					
Missouri Rolling Mill Corp.	St. Louis	Mo.					345 173					
National Steel Corp. (Great Lakes Div.)	Ecorse	Mich.	4315	9493	1450 863		734 404					6904 10356
(Weirton Steel Div.)	Weirton	W. Va.	8917					1036				8918

Table XXIX

ROLLING MILL FACILITIES AND DAILY CAPACITY

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
Northstar Steel Co.	St. Paul	Minn.					719					
Northwest Steel Rolling Mills, Inc.	Seattle	Wash.	863				575					
Northwest Steel & Wire Co.	Sterling	Ill.	4315		4315			863 863		1036	863	
Pacific States Steel Corp.	Union City	Calif.					719 432					
Phoenix Manuf. Co.	Joliet	Ill.					460 72					
Phoenix Steel Corp.	Claymont	Del.		1295		1295						
Phoenix Steel Corp.	Phoenixville	Pa.	863				327 173					
Pollak Steel Co.	Marion	Ohio					460 460 460 460 230 230					
Portec, Inc.	Troy	N.Y.					35					
H. K. Porter Co. (Connors Steel Div.)	Birmingham	Ala.					432 260					
H. K. Porter Co. (Connors Steel Div.)	Huntington	W. Va.	432				260 130					

Table XXIX

ROLLING MILL FACILITIES AND DAILY CAPACITY

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
Republic Steel Corp.	Youngstown	Ohio	3538 1611 (Skelp)		1582		440 334					
Republic Steel	Warren	Ohio	4715									6030 863
Republic Steel	Massilon	Ohio	1640		1824		1412 58					
Republic Steel	Canton	Ohio	2589				1110 455					115 (Jobbing)
Republic Steel	Cleveland	Ohio	2934	8164	2013		1036 739					6283 8751
Republic Steel	Buffalo	N.Y.	2744		1582		1036 587 316					
Republic Steel	South Chicago	Ill.	5351		863		2954 1749 1151 828			475		
Republic Steel	Gadsden	Ala.	3832			1484	342					3553
Roblin Steel Co.	N. Tonawands	N.Y.					345					
Sharon Steel Corp.	Farrell	Pa.	2014	3452								4833 1553 828

Table XXIX

ROLLING MILL FACILITIES AND DAILY CAPACITY

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
Simonds Steel Div. (Wallace Murray Corp.)	Lockport	N.Y.	16 (Cogging)			5	7 18					9 4 (Band)
Solar Steel Corp.	Cleveland	Ohio										104 29
Soulé Steel Co.	Long Beach	Calif.					288					
Southwest Steel Rolling Mills, Inc.	Los Angeles	Calif.							288			
Structural Metals Inc.	Seguin	Texas					259 29					
Tenn. Forging Steel Corp.	Harriman	Tenn.					345					
Texas Steel Co.	Ft. Worth	Texas					360					
The Timken Co.	Canton	Ohio	1740		1740		1007 518 22					
United States Steel Corp.	Clairton	Pa.						524 553 853 673				
U. S. Steel	Homestead	Pa.	2284 2301	8855		2063 2759 719		1490 2103				
U. S. Steel	Chicago South Works	Ill.	3231 3267	6875		2690 685	790	1622				

Table XXIX

ROLLING MILL FACILITIES AND DAILY CAPACITY

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
U. S. Steel	Joliet	Ill.								1794 972	130	
U. S. Steel	Edgar Thomson Braddock	Pa.		6228								
U. S. Steel	Irwin Works Drauosburg	Pa.										8046
U. S. Steel	Fairfield	Ala.	3306 5774	(201) (Hoop & cotton tie)	2051 1299	1481	509 135 186	1140	1673	577		4853
U. S. Steel	Fairless Hills	Pa.	4890	8342			863			1309		8055 2693 (Skelp)
U. S. Steel	Gary	Ind.	2244 1242	11369	5236	3464	921 524 619 500 811 263 536 676 416		3067			1131 547 8871 12715
U. S. Steel	Geneva	Utah	6313 (Slad & Bloom)					1265				5933
U. S. Steel	Pittsburgh	Calif.								801		
U. S. Steel	Torrance	Calif.					553	475				

Table XXIX

ROLLING MILL FACILITIES AND DAILY CAPACITY

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
U. S. Steel	McKeesport	Pa.	3065				2951					
U. S. Steel	Duquesne	Pa.	4875				975 679 996					
U. S. Steel	Lorain	Ohio	461 5158				461 1738 1571 1850					
U. S. Steel	Cleveland	Ohio								1251 541		311
U. S. Steel	Youngstown	Ohio	2607	2992			254 524 518 269 838		159 (Hoop) 658 (Hoop)			3815 951 464
U. S. Steel	Duluth	Minn.	2193		2086		405		454			
Vasco Metals Inc.	Monroe	N.C.					36					
Vasco Metals Inc.	Latrobe	Pa.					43 14 14 26					
Wheeling Pittsburgh Steel Corp.	Steubenville	Ohio	3797	4833								4143 6904

Table XXIX

ROLLING MILL FACILITIES AND DAILY CAPACITY

Company	Plant	State	Blooming	Slabbing	Billet	Plate	Bar	Structural	Rail	Rod	Merchant	Hot Strip & Sheet
Wheeling-Pgh.	Monesson	Pa.	3740		1438 1151							
Wheeling-Pgh	Allenport	Pa.										2589
Youngstown S & T Co	Campbell	Ohio	4902		1553		483 380					7125
Youngstown S & T	Youngstown	Ohio	4004 3417		1622							
Youngstown S & T	Ind. Harbor East Chicago	Ind.	3452	7491	2036		932 518					8630

Pickling

Pickling is the process of chemically removing oxides and scale from the surface of the steel by the action of water solutions of inorganic acids. Depending on the type of product being processed, a number of acids such as Sulfuric, Hydrochloric, Nitric, Hydrofluoric, and Phosphoric, either individually or in combination may be utilized in both batch and continuous equipment. In 1950, Sulfuric acid accounted for more than 90% of the tonnage pickled, however in recent years an increasing number of steel mills have changed to hydrochloric acid. Hydrochloric acid offers several advantages over sulfuric acid; it produces a more even and cleaner surface, requires lower liquor temperatures and can be regenerated.

Some products such as tubes and wire are pickled in batch operations; that is, the product is immersed in an acid solution and allowed to remain in this solution until the scale or oxide film is removed. The material is lifted from the bath, allowed to drain, and rinsed by sequential immersion in rinse tanks.

Pickling lines for hot-rolled strip operate continuously on coils that are welded together, passed through the pickler, then sheared and recoiled. The steel passes through the pickler countercurrently to the flow of the acid solution. Most mild steel is pickled with sulphuric or hydrochloric acid; stainless steels are pickled with hydrochloric, nitric, and hydrofluoric acids. Warious organic chemicals are used in pickling to inhibit acid attack on the base metal, while permitting preferential attack on the oxides; wetting agents are used to improve the effective contact of the acid solution with the metal surface. As in the batch operation the steel passes from the pickling bath through a series of rinse tanks.

One recent estimate[1] indicates that about one-half of the spent pickle liquor produced by the steel industry is discharged without treatment, this despite the fact that spent pickle liquor has been the subject of research and development studies for more than 40 years. The various processes which have been developed are too numerous to tabulate; there are well over 150 patented processes alone. The following list includes the major processes.

Neutralization Processes:

- High Calcium Lime
- Dolomitic Lime
- Limestone
- Limestone and Lime
- Dry Lime
- Molten Blast Furnace Slag

Neutralization with Air Oxidation(Mellon, A.O. Smith, DuPont)

Recovery Processes:

- Copperas (cooling, evaporation, differential solubility)
- Ferrous sulfate monohydrate (Martin, Chemica)
- Ferric sulfate
- Coke oven gas processes (Elzi, Tiddy, Mellon, Williputte)
- Ammonium sulfate (Pure Ammonia)

Construction Material Production (Ferron)

Extraction Processes:

- Manganese from low grade ores
- Magnesia from Dolomite

Regeneration Processes:

- Electrolytic Regeneration
- Lurgi Fluidized Bed Process
- Lurgi Refrigeration Process
- Blaw-Knox Ruthner Processes (H_2SO_4)
- Haveg Turbulator Process
- Chemical Separations Ion Exchange Process (Higgins)
- Dravo-Ruthner Process (HCl)

Deepwell Disposal

Co-Treatment:

Rolling Mill Effluent Clarification
Wool Scouring Wastes
Coke Plant Wastes

Contract Hauling

Sale:

For Water Treatment
For Waste Treatment
For Manufacturing Uses

Barging to Sea

The sources of wastewater frompickling operations are the strong spent solutions, the rinsewaters, and the water used in fume scrubbers. The latter source is generally found when other than sulfuric or phosphoric acids are used; due to the volatilities and noxious character of the fumes from hydrochloric, nitric, and hydro fluoric acids, scrubbers are used largely as an industrial hygiene measure.

CARBON STEEL PICKLING

Raw Waste Loads - Sulfuric Pickling

About 50% of all carbon steel products are pickled. Most alloy steel products are pickled, and all stainless steel products are pickled.

In 1967, S.I.C. 3312 establishments used 1.089 million tons of sulfuric acid, compared with 1.176 million tons in 1963. Carbon steel products totaled 76.042 million tons in 1967 and 69.510 million tons in 1963. The sulfuric acid used in pickling is thus estimated presently at about 22 pounds of acid per ton of carbon steel products. The typical spent liquor from a continous strip pickler contains 8.5% free H_2SO_4 and 13.0% Fe SO_4, weighing about 10 lbs. per gallon; the liquor is typically made up at 20% H_2SO_4 (Sp. gr. = 1.14). About 12.5% of the free and combined acid in the spent liquor is lost in the rinsewater. Expressed then in terms of total carbon steel products, raw wasteloads are as follow:

Basis: 1.000 gal. pickle liquor

Spent Liquor = 0.875 gal. x 10 lb./gal. = 8.75#

8.75 x 0.085 = 0.744# H_2SO_4

8.75 x 0.130 = 1.138# $FeSO_4$ $\frac{98}{152}$ x 1.138 = 0.734 # H_2SO_4

Original acid equivalent in WPL = 1.478# H_2SO_4

Rinsewater = $\left(\frac{.125}{.875}\right)$ 0.744 = 0.106# H_2SO_4

= $\left(\frac{.125}{.875}\right)$ 1.138 = 0.163# $FeSO_4$ 0.105 # H_2SO_4

Original acid equivalent in rinsewater = 0.211 # H_2SO_4

The original liquor thus contained 1.689# H_2SO_4 per gal., equivalent to about an 18% solution at 20°C:

1.1243 x 8.33 x 0.18 = 1.686 #/gal.

The raw waste load for the spent liquor are thus:

(0.875 x 22) ÷ 1.689 = 11.4 gals./ton

(11.4 x 10) x 0.085 = 9.69 lbs. H_2SO_4/ton

(11.4 x 10) x 0.130 = 14.82 lbs. $FeSO_y$/ton 5.46 lbs. Fe/ton

The constituent raw waste loads for the rinsewater are:

$\left(\frac{.125}{.875}\right)$ x 9.69 = 1.38 # H_2SO_4/ton

$\left(\frac{.125}{.875}\right)$ x 5.46 = 0.78 #Fe/ton 2.12 #$FeSO_4$/ton

The above data are in terms of production of carbon steel products. Since sulfuric acid pickling generally requires 45 pounds of acid per ton of steel pickled, the above can be multiplied by 45/22, or 2.05 for an expression in terms of carbon steel pickled per ton of steel pickled. Rinsewater volumes are given in the NUS report at 500 gal./ton of steel. This is about right on the basis of the H. H. Robertson plant at Ambridge, Pa. The rinsewater rate there was 110 gpm at a throughput of 150 feet per minute. At 1 lb. per square foot for a 36" sheet, the rinsewater rate is 489 gals. per ton.

Converting all of the above then to the basis of tons of steel pickled:

Strong Spent Liquor

Volume= 11.4 x 2.05 = 23.4 gals. per ton

Iron = 5.46 x 2.05 = 11.19 lbs. per ton

Free Acidity as $CaCO_3$:

$1.38 \times 2.05 \times \frac{100}{98} = 2.89$ lbs. per ton

Total Acidity as $CaCO_3$:

$1.38 \times 2.05 \times \frac{100}{98} = 2.89$

$2.12 \times 2.05 \times \frac{100}{152} = \underline{2.86}$

5.75 lbs. per ton

Iron in the rinsewater as above would be 384 ppm, well within the 300-700 ppm range experienced at the Ambridge plant. The spent liquor volume of 75 gpm at National Steel, Midwest Division is equivalent to about 16 gals. per ton pickled, assuming that the 2,360,000 ton per year cold reduction capacity is pickled. The spent liquor there contains 16% $FeSO_4$, and the volume would thus be expected to be somewhat lower; the indicated Fe waste load is 9.43 lbs.per ton. The available data thus seem to substantiate the above raw waste loads.

Raw Waste Loads - Hydrochloric Pickling

The 100 gpm spent liquor from Armco's new (1969) facilities at Middletown, Ohio presumable results obtained from processing about 1,680,000 tons annually, equivalent to 29.8 gals/ton. The

130 gpm flow at J & L's Hennepin Works is about 52 gals. per ton on the basis of the 1,250,000 ton per year tandem mill. Armco reports 20-25% $FeCl_2$ in the WPL; J & L 16-21%. Both indicate 0-1% free acid; Watkins gives an average value of 0.25% free acid. On the basis of the above, a WPL volume of 41 gals. per ton is indicated with an $FeCl_2$ concentration of 20% and a free acid concentration of 0.5%. The specific gravity would be about 1.21. The data at Armco indicate a rinsewater volume of about 7.75 times that of the strong liquor volume, containing an average of 190 ppm Fe and 510 ppm acidity. The raw waste loads are thus estimated as follows:

Strong Spent Liquor

Volume = 41 gals. per ton

Iron = $41 \times 8.33 \times 1.21 \times 0.20 \times \frac{56}{127} = 36.4$ lbs. per ton

Free Acidity as $Ca\,CO_3$:

$0.005 \times 41 \times 8.33 \times 1.21 \times \frac{100}{2\times36.5} = 2.83$ lbs. per ton

Total Acidity as $Ca\,CO_3$:

$$
\begin{array}{rr}
0.005 \times 41 \times 8.33 \times 1.21 \times \frac{100}{2\times36.5} & = 2.83 \\
41 \times 8.33 \times 1.21 \times 0.20 \times \frac{100}{127} & = \underline{65.1\quad} \\
 & 67.93 \text{ lbs. per ton}
\end{array}
$$

Rinsewater:

Volume = $7.75 \times 41 = 318$ gals. per ton

Fe = $218 \times 8.33 \times 10^{-6} \times 190 = 0.50$ lbs. per ton

Total Acidity as HCl = $318 \times 8.33 \times 10^{-6} \times 510 = 1.35$ lbs. per ton

Combined Acidity as HCl = $0.50 \frac{36.5\times2}{\times 56} = 0.65$ lbs. per ton

Free Acidity as HCl = $1.35 - 0.65 = 0.70$ lbs. per ton

Free Acidity as $Ca\,CO_3$ = $0.70 \times \frac{100}{2 \times 36.5} = 0.96$ lbs. per ton

Total Acidity as $Ca\,CO_3$ = $1.35 \times \frac{100}{2 \times 36.5} = 1.85$ lbs. per ton

The Steel Company of Canada at Hamilton, Ontario reported (Iron and Steel Engineer, August, 1971) an HCl spent liquor volume of 40 gpm at a pickling rate of 500,000 tons annually. At 20 shifts per week, this is equal to 40 gals per ton as estimated above.

ALLOY AND STAINLESS STEEL PICKLING

The production of stainless steel strip typically proceeds as follows:

1. Hot-rolled strip (0.125"), annealed, and pickled in two 35-foot long tanks containing 15% hydrochloric acid at 160°F, followed by a single similar tank containing 4% hydrofluoric acid and 10% mitric acid at 150-170° F.
2. Cold reduction to 0.060" using soluable oils, followed by annealing and pickling in HNO_3 - HF.
3. Cold reduction to 0.030" using soluable oils, followed by annealing and pickling in HNO_3 - HN.
4. Cold reduction to 0.013" - 0.015" using soluble oils, followed by annealing and pickling in HNO_3- HF.
5. Temper mill finishing to 0.010" using a kerosene type solution such as Stanisol.

The production of stainless steel billets, bars, and plates typically involves a single pickling operation in a 10% sulphuric acid solution at 140°-160°F, followed by a 10% HNO_3, 4% HF bath at 130°-150°F.

The alloy steels, depending upon the grade, are pickled in a great variety of acids and combinations of acids. Sulfuric acid alone is usually ineffective. Various combinations of sulfuric, hydrochloric, nitric, and phosphoric acid are used.

According to Shreve, about 27% of the hydrofluoric acid produced in 1963 was used in the metal and petroleum industries. According to the Petroleum Industry Profile, in 1963 about 42% of alkylation units used HF, and this operation had a capacity equal to 6% of the typical refinery throughput. On the basis of the 1963 throughput of 3.156 billion bbls., HF alkylation capacity was 79.53 million bbls. per year. According to Nelson, about 0.55 lbs. of acid is consumed or lost per barrel. The indicated 1963 use in the petroleum industry was thus about 22,000 tons. Of the 105,000 ton production in 1963 then, about 6,000 tons was presumable used in the steel industry.

Stainless steel shipments in 1963 was 667,701 tons, indicating an overall use of HF of about 18 lbs. per ton. Nitric acid use would thus be expected to be about 18 x 2.5, or 45 lbs. per ton. Cold rolled sheet and strip totaled 359,217 tons and hot rolled sheet and strip 36,016 tons. The use of HCl and H_2SO_4 are thus estimated as follows on the basis of 59% hot rolling of sheets and strip, and 41% production of other products.

$$0.59 \times 18 \times \frac{2 \times 15}{4} = 79.7 \text{ lbs. HCl per ton}$$

$$0.41 \times 18 \times \frac{10}{4} = 18.5 \text{ lbs. } H_2SO_4 \text{ per ton}$$

The total indicated volumes of pickle liquor per ton then is as follows assuming a density of 10 lbs. per gallon:

$$\frac{18}{0.04} \times 10 = 45 \text{ gals. } HNO_3\text{-HF liquor per ton of stainless}$$

$$\frac{79.7}{0.15 \times 10} = 53 \text{ gals. HCl liquor per ton hot-rolled sheet strip}$$

$$\frac{18.5}{0.10 \times 10} = 18.5 \text{ gals. } H_2SO_4 \text{ liquor per ton bars, plates, and billets}$$

The practice in cold rolled sheet and strip production in 1963 probably averaged that indicated in Making and Shaping-1964 (p.1119), i.e., one pickling following cold rolling. With two additional picklings now during cold rolling of sheet and strip, about twice as much HND3-HF pickle liquor would be expected to be used for that portion of the stainless production. The HND_3-HF liquor may now amount ot 50% more than the above estimates. The production of hydrofluoric acid increased by about 43% from 1963 to 1967, indicating, at least, that this conclusion is not impossible.

Raw wastes loads for stainless pickling are thus estimated as follows with the assumption of rinsewater volumes and free acid concentrations as with HCland H_2SO_4pickling of carbon steel for these solutions, and as with HCl pickling of carbon steel for HNO_3-HF solutions; free acid concentrations in the strong liquors are similarly assumed.

HNO_3 - HF Pickling (lb. per ton of Stainless Production)

Carbon steel HCl acidities as $CaCO_3$ for calculations:

Total acidity in HCl spent liquor and rinse = 67.93 + 1.85 = 69.78

Free acid in HCl spent liquor = 2.83; in rinsewater = 0.96

Combined acid in HCl spent liquor = 65.10; in rinsewater = 0.89

Strong Spent Liquor

$$\text{Free HF} = \left(\frac{2.83}{69.78}\right) \times 1.5 \times 18 = 1.10 \text{ lbs. HF}$$

$$\text{Free } HNO_3 = \left(\frac{2.83}{69.78}\right) \times 1.5 \times 45 = 2.74 \text{ lbs } HNO_3$$

$$\text{Combined Acid} = \left(\frac{65.10}{69.78}\right) \times 1.5 \times 18 = 25.19 \text{ lbs. as HF}$$

$$\text{Combined Acid} = \left(\frac{65.10}{69.78}\right) \times 1.5 \times 45 = 62.97 \text{ lbs. as } HNO_3$$

$$\text{Iron} = 25.19 \times \left(\frac{56}{2 \times 20}\right) + 62.97 \times \frac{56}{2 \times 63} = 63.3 \text{ lbs. Fe}$$

Total acidity as $CaCO_3$:

$$(1.10 + 25.19) \left(\frac{100}{2 \times 20}\right) = 65.73$$

$$(2.74 + 62.97) \left(\frac{100}{2 \times 63}\right) = \underline{52.15}$$

$$117.88 \text{ lbs. as } CaCO_3$$

Free acidity as $CaCO_3$:

$$1.10 \times \left(\frac{100}{2x20}\right) + \left(2.74 \times \frac{100}{2x63}\right) = 4.92 \text{ lbs. as } CaCO3$$

Volume = 45 x 1.5 = 67.5 gallons

Rinsewater

Free HF = $\left(\frac{0.96}{69.78}\right) \times 1.5 \times 18 = 0.37$ lbs. HF

Free HNO_3 = $\left(\frac{0.96}{69.78}\right) \times 1.5 \times 45 = 0.93$ lbs. HNO_3

Combined Acid = $\left(\frac{0.89}{69.78}\right) \times 1.5 \times 18 = 0.34$ lbs. as HF

Combined Acid = $\left(\frac{0.89}{69.78}\right) \times 1.5 \times 45 = 0.86$ lbs. as HNO_3

Iron = $\left(0.34 \times \frac{56}{2x20}\right) + \left(0.86 \times \frac{56}{2x63}\right) = 0.86$ lbs. Fe

Total acidity as $CaCO_3$:

$$(0.37 + 0.34) \left(\frac{100}{2x20}\right) = 1.78$$

$$(0.93 + 0.86) \left(\frac{100}{2x63}\right) = \underline{1.42}$$

3.20 lbs. as $CaCo_3$

Free Acidity as $CaCO_3$:

$$\left(0.37 \times \frac{100}{2x20}\right) + \left(0.93 \times \frac{100}{2x63}\right) = 1.67 \text{ lbs. as } CaCO_3$$

Volume = 7.75 x 67.5 = 523 gallons

HCl Pickling (per ton hot-rolled sheet and strip)

HCl carbon steel pickling = $69.78 \times \frac{36.5}{100} = 25.47$ lbs. HCl per ton

Strong Spent Liquor

Volume = 53 gallons

Iron = $\frac{79.7}{25.5} \times 36.4 = 113.8$ lbs.

Free acidity as $CaCO_3$ = $\frac{79.7}{25.5} \times 2.83 = 8.85$ lbs.

Total acidity as $CaCO_3$ $\frac{79.7}{25.5} \times 67.93 = 212$ lbs.

Rinsewater:

Volume = 7.75 x 53 = 411 gallons

Iron = $\frac{79.7}{25.5} \times 0.50 = 1.56$ lbs.

Free acidity as $CaCO_3$ = $\frac{79.7}{25.5} \times 0.70 = 2.19$ lbs.

Total acidity as $CaCO_3 = \frac{79.7}{25.5} \times 1.85 - 5.78$ lbs.

H_2SO_4 Pickling (per ton bars, plates and billets)

H_2SO_4 carbon steel pickling = 45 lbs. H_2SO_4 per ton

Strong Spent Liquors

Volume = 18.5 gals.

Iron = $\frac{18.5}{45} \times 11.19 = 4.60$ lbs.

Free acidity as $CaCO_3 = \frac{18.5}{45} \times 20.27 = 8.33$ lbs.

Total acidity as $CaCO_3 = \frac{18.5}{45} \times 40.26 = 15.66$ lbs.

Rinsewater

Volume = $\frac{18.5}{23.4} \times 500 = 395$ gallons

Iron = $\frac{18.5}{45} \times 1.60 = 0.66$ lbs.

Free acidity as $CaCO_3 = 18.5/45 \times 2.89 = 1.19$ lbs.

Total acidity as $CaCO_3 = 18.5/45 \times 5.75 = 2.36$ lbs.

Raw waste loads for pickling are thus estimated in Table 1 on the basis of units per ton of steel pickled, averaging those for alloy steel production on the basis of 50% as for stainless 0.50 $\left(\frac{22}{45}\right)$ as for sulfuric pickling of carbon steel, and 0.50 $\left(\frac{45-22}{45}\right)$ as for hydrochloric pickling of carbon steel.

Alloy steel pickling, as previously indicated, uses such a variety of procedures that general raw waste loads can not be estimated on the basis of any hard data. A reasonable approximation, however, can be made on the basis of the averages of carbon and stainless steel practice.

	Raw Waste Loads (16 per ton pickled).		
	Carbon Steel	Stainless	Alloy
H_2SO_4 Pickling			
Volume, gals.	23.4	18.5	14.9
Iron, lbs. Fe	11.2	4.60	4.99
Free Acidity, lbs. $CaCO_3$	20.3	8.33	9.04
Total Acidity, lbs. $CaCO_3$	40.3	16.6	18.0
Sulfate, lbs. SO_4	38.7	15.9	17.2
HCl Pickling			
Volume, gals.	41.0	53.0	37.2
Iron, lbs. Fe	36.4	114	66.5
Free Acidity, lbs. $CaCO_3$	2.83	8.85	5.17
Total Acidity, lbs. $CaCO_3$	67.9	212	124
Chloride, lbs. Cl	48.2	151	88.0
HND_3 -HF Pickling			
Volume, gals.	-	67.5	33.8
Iron, lbs. Fe	-	63.3	31.7
Free Acidity, lbs. $CaCO_3$	-	4.92	2.46
Total Acidity, lbs $CaCO_3$	-	118	59.0
Fluoride, lbs. F	-	25.0	12.5
Nitrate, lbs. NO_3	-	64.7	32.4
H_2SO_4 Rinsewater			
Volume, gals.	500	395	318
Iron, lbs. Fe	1.60	0.66	0.71
Free Acidity, lbs. $CaCO_3$	2.89	1.19	1.29
Total Acidity, lbs. $CaCO_3$	5.75	2.36	2.56
Sulfate, lbs. SO_4	5.52	2.27	2.46
HCl Rinsewater			
Volume, gals.	318	411	282
Iron, lbs. Fe	0.50	1.56	0.90
Free Acidity, lbs. $CaCo_3$	0.96	2.19	1.33
Total Acidity, lbs. $CaCo_3$	1.85	5.78	3.33
Chloride, lbs. Cl	1.31	1.40	1.01
HNO_3 -HF Rinsewater			
Volume, gals.	-	52[illegible]	262
Iron, lbs. Fe	-	0.86	0.43
Free Acidity, lbs. $CaCO_3$	-	1.67	0.84
Total Acidity, lbs. $CaCO_3$	-	3.20	1.60
Fluoride, lbs. F	-	0.68	0.34
Nitrate, lbs. ND_3	-	1.76	0.88

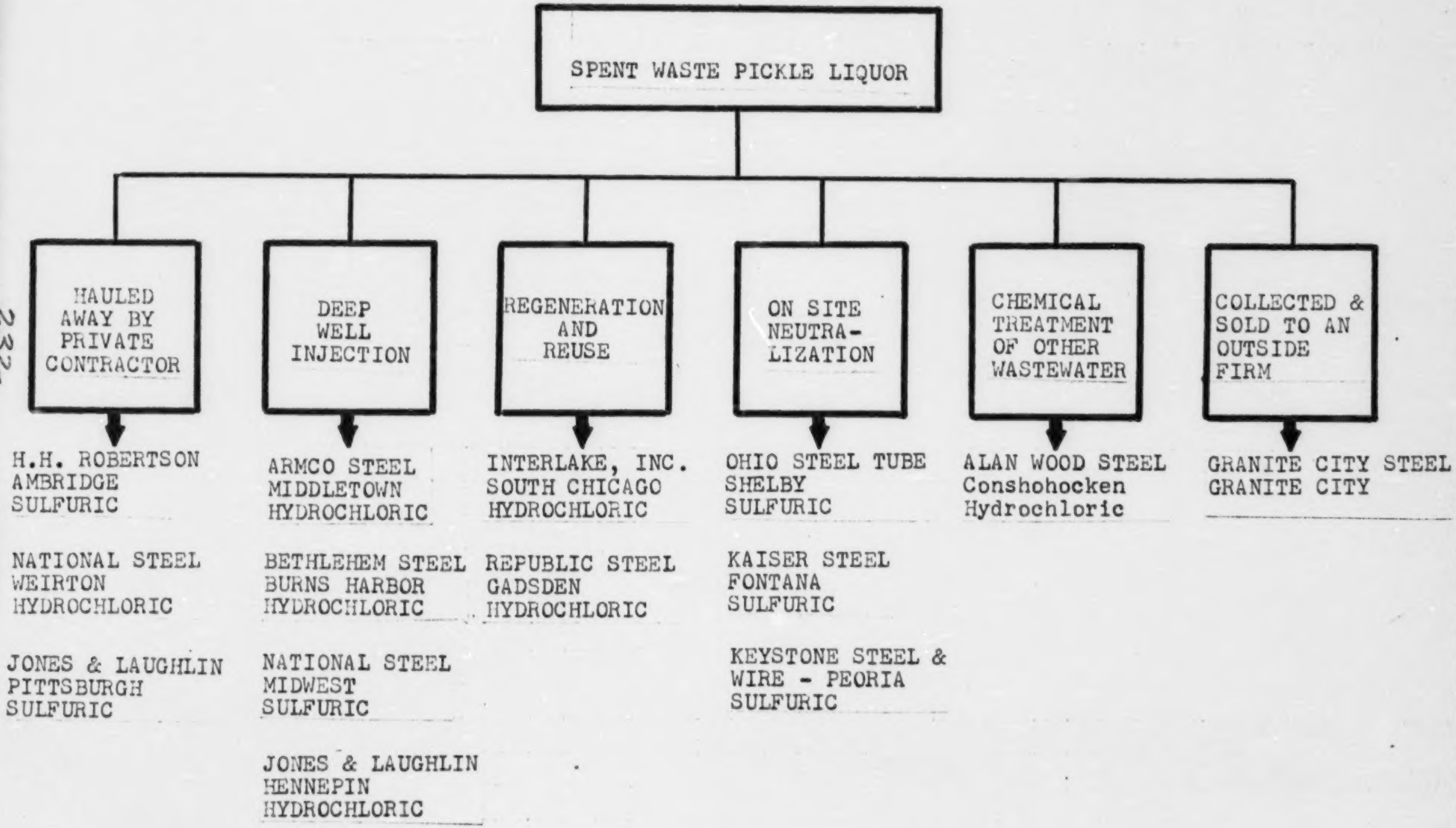
PICKLING WASTES TREATMENT METHODS

The usual treatment methods for strong spent pickle liquors are contract hauling, lime neutralization, and deepwell disposal. Regeneration of HCl liquors is practiced at the Steel Company of Canada, Ontario, and at Republic Steel Corporation, Gadsden, Alabama. Some portion of the Strong liquor can be used as a source of iron salts for the clarification of rolling mill wastes. A macimum use at an integrated mill is probably about 20% of the total volume of the strong liquor produced.

Rinsewaters are generally treated by neutralization in a separate facility or are combined with the total mill effluent, with or without the addition of an alkaline agent. The latter methods of treatment can be considered as a type of co-treatment.

FIGURE 25

EXAMPLES OF ALTERNATIVE METHODS OF DISPOSING OF SPENT PICKLE LIQUOR


SPENT WASTE PICKLE LIQUOR
HAULED AWAY BY PRIVATE CONTRACTOR
DEEP WELL INJECTION
REGENERATION AND REUSE
ON SITE NEUTRALIZATION
CHEMICAL TREATMENT OF OTHER WASTEWATER
COLLECTED & SOLD TO AN OUTSIDE FIRM
H.H. ROBERTSON AMBRIDGE SULFURIC
NATIONAL STEEL WEIRTON HYDROCHLORIC
JONES & LAUGHLIN PITTSBURGH SULFURIC
ARMCO STEEL MIDDLETOWN HYDROCHLORIC
BETHLEHEM STEEL BURNS HARBOR HYDROCHLORIC
NATIONAL STEEL MIDWEST SULFURIC
JONES & LAUGHLIN HENNEPIN HYDROCHLORIC
INTERLAKE, INC. SOUTH CHICAGO HYDROCHLORIC
REPUBLIC STEEL GADSDEN HYDROCHLORIC
OHIO STEEL TUBE SHELBY SULFURIC
KAISER STEEL FONTANA SULFURIC
KEYSTONE STEEL & WIRE - PEORIA SULFURIC
ALAN WOOD STEEL Conshohocken Hydrochloric
GRANITE CITY STEEL GRANITE CITY

WASTE TREATMENT FOR PICKLING WASTEWATERS

The waste treatment methods for wastewaters from pickling may be grouped as follows:

Strong Spent Liquor:

1. Contract Hauling
2. Deepwell Disposal
3. Lime Neutralization
4. Regeneration:
    a. Hydrachloric Liquor
    b. Sulfuric Liquor

Rinsewaters:

1. Co-treatment
2. Neutralization

The listings above are in the order of preferred utilization insofar as the industry is concerned.

Contract Hauling

Contract hauling is used whenever possible because there are no capital costs aside from collection and storage facilities; the flat charge per gallon is a wholly tax-deductible operating expense; and the plant operator has a minimum of bother with the problem. The average cost is probably about 2¢ per gallon.

Deepwell Disposal

Deepwell disposal is the next preferred method because both capital and operating costs are the lowest of in-plant methods before credits. The plant operator has little bother with what is essentially an automated operation.

One of the most critical factors in this disposal method is the required injection pressure which ranges from 0 to 3,000 psig. The following 3 cases cover the range experienced:

Plant	Location	Injection Pressure	Rate
Jones & Laughlin	Aliquippa, Pa.	3,000 psi	--
Armco Steel	Middletown, Ohio	500 psi	100 gpm
National Steel	Portage, Indiana	0 psi	75 gpm

The capital costs for deepwell disposal at 100 gpm are not much affected by injection pressure and for average geological conditions, such a well would cost about $200,000 (1969) with minimum pretreatment by filtration (Inorganic Chemical Profile). With the 1972 ENR Index approaching 1800 (1969 = 1285), 1972 costs are probably about $280,000. Collection facilities and ancillary equipment probably give a total cost of about $500,000.

Operating costs at Portage were $5,182 per month in 1966. About 23 million gallon had been injected in 18 months. The operating costs were thus $0.004 per gallon, not including capital charges. At 3.5% per year, 1972 costs are probably about $0.005 per gallon.

It should be noted that standby lime neutralization facilities have been installed with some deepwell installations such as at Portage. Total capital costs must thus be looked at carefully to determine whether or not this type of cost is included.

Neutralization

Lime neutralization for strong spent liquor is basically of two types: conventional lime neutralization which produces a bulky, permanently wet sludge and air oxidation to produce a settleable, filterable sludge which can be used to produce a dry fill material. The latter include the Mellon magnetic iron oxide, the Eimco, and the DuPont processes; all are essentially the same.

The differences in capital costs between the conventional and air oxidation processes are relatively little. The operating costs for the air oxidation processes are lower because of savings in sludge disposal costs. Costs in 1959 were as follows for 100,000 gpd of H_2SO_4 WPL:

	Eimco Process	Conventional
Capital costs	$ 935,000	$ 900,000
Annual operating cost	673,200	953,650

On the basis of the ENR Cost Index, the 1972 capital costs for this type of facility are probably about double the above. The operating costs in 1972 at 3.5% per year would be about $0.030 and $0.043 per gallon for the air oxidation and conventional processes, respectively.

The performance of such treatment systems can be best estimated from the work reported by Keystone Steel and Wire, Peoria, Illinois. Iron in the supernatant liquor after lime neutralization can probably be reduced to 15 ppm. With air oxidation at elevated temperatures (80°C), iron in the effluent can be reduced to essentially zero. The pH of the reaction, and hence the effluent, must be above 8.0 for the above results. The solubility of calcium sulfate is about 2,000 ppm and would be excepted in the effluent. Calcium nitrate is 1,000 more soluble than calcium sulfate. Calcium chloride has 112 the solubility of calcium nitrate. Calcium fluoride is about 1/100th as soluble as calcium sulfate.

The effluents from lime neutralization of WPL are thus estimated as follows, assuming that air oxidation will be less than 100% efficient, but at least equivalent to results with rinsewater:

	Conventional	Air Oxidation
Iron	15 ppm	4 ppm
pH	8.0	9.0
Calcium Sulfate	2000 ppm	2000 ppm
Calcium Nitrate	Raw Load	Raw Load
Calcium Chloride	Raw Load	Raw Load
Calcium Fluoride	20 ppm	20 ppm

For the case of pickling rinsewaters, costs are best estimated on the basis of the Armco demonstration project at Middletown, Ohio. Total Fe in the effluent averaged 4.0 ppm turbidity, turbidity 10 ppm, and pH 6.9. Even a superficial purusal of the data for April, 1970 show that pH below 6.8 and temperatures below 115°F are less than optimum. The other constituents in the effluent may be deduced from the above data for the strong spent liquor up to the limits of the raw waste loads.

Iron	4 ppm
pH	6.9
Turbidity	10 ppm
Calcium Sulfate	< 2000 ppm
Calcium Nitrate	Raw Load
Calcium Chloride	Raw Load
Calcium Fluoride	20 ppm

In the recommended operation of the DuPont Process, high calcium lime is added as a 25 percent slurry. This added volume need not be considered as an addition to the total waste volume, since treated rinsewater can be used to make up the slurry. Effluent suspended solids should probably be taken at 15 ppm for the total pickling operation, since this can be achieved according to the Armco data in treating rinsewater and the treated pickle liquor effluent should be the vacuum filter filtrate. The latter, in the worst case, could be discharged through the rinsewater clarifiers. Co-treatment of rinsewater would produce a similar effluent if the total wastes were sand filtered, i.e., received the best available treatment.

The Armco data indicate operating costs of $0.24 per 1,000 gallon of rinsewater. The capital costs of a facility to treat 1,500 gpm, or 2.16 mgd, were $1,360,000.

Regeneration of Spent Liquor

Of the many technically feasible processes, the Lurgi and Dravo-Ruthner processes for hydrochloric liquors and the Higgins and Blaw-Knox Ruthner processes for sulfuric acid liquors are probably best representative of the costs involved. Effluent waste loads would be essentially zero. The Dravo - Ruthner process is installed and in operation at Republic Steel, Gadsden, Alabama at the Steel Company of Canada, Ontario, and at McClouth Steel Corporation in Detroit. Republic reportedly plans another installation in Cleveland. The Higgins process has been demonstrated under an EPA grant and was at one time enthusiastically regarded by industry representatives as the best solution for sulfuric acid spent liquor treatment. The Blaw-Knox Ruthner process was demonstrated in a large-scale pilot plant by a steel industry consortium in the early 1950's.

The Steel Company of Canada plant cost $2 million in 1966 to treat 30 gpm of spent HCl liquor. In 1969, they reported an operating cost of 60¢ per ton of steel pickled. The Lurgi fluidized bed process for HCl regeneration operates on the same chemical principle as the Dravo-Ruthner process. A battery-limits plant to treat 13.9 gpm of spent liquor reportedly cost $480,000 in 1972, and an operating cost of 50¢ to $1 per ton of steel pickled was quoted in 1966. The process was commercialized in Germany in 1966 and some 25 plants have been built around the world - none in the U. S.

Plants to treat 100,000 gpd, or 69.4 gpm, would thus cost as follows on the basis of the M & S Equipment cost index and assuming double the battery limits cost for a complete plant:

$$\$2,000,000 \quad \frac{140}{110} \quad \left(\frac{69.4}{30.0}\right)^{0.6} = \$4,208,000 \text{ (Dravo-Ruthner)}$$

$$(2 \times \$480,000) \quad \left(\frac{69.4}{13.9}\right)^{0.6} = \$2,525,000 \text{ (Lurgi)}$$

A capital cost of $4,000,000 for a 100,000 gpd HCl regeneration plant thus seems to be a conservative estimate. An operating cost of $0.60 per ton of steel pickled is indicated.

The direct operating costs for a 100,000 gpd Higgins process plant for sulfuric acid regeneration have been estimated at $893 per day, or $326,000 per year. A 100,000 gpd Blaw-Knox Ruthner plant was estimated at $4,113,000 in 1959 with total direct operating costs of $821,330 annually. On the basis of the M & S Equipment Cost Index, 1972 costs for a 100,000 gpd Blaw-Knox Ruthner plant would be about 1.4 x $4,113,000, or $5,758,000. Had operating costs increased proportionately, 1972 direct annual costs would be $1,150,000.

A conservative estimate of the 1972 cost of a sulfuric acid regeneration plant for 100,000 gpd thus appears to be about $6,000,000 with direct operating costs of about $1,000,000.

The regeneration processes generate at least enough credits in recovered acid and iron oxide to cover direct operating costs. Operating costs, as used herein, are thus essentially zero; capital charges and other indirect costs must, of course, be considered.

Assuming then that neutralization with air oxidation and vacuum filtration of the sludge is the Best Practicable Treatment for strong spent liquors and is also the Best Available Treatment for HNO_3-HF liquors, that regeneration is the Best Available Treatment for H_2SO_4 and HCl liquors, and that co-treatment or neutralization with air oxidation is the sole treatment for rinsewaters, effluent wasteloads for pickling are as shown in Table XXX

Table XXX - Treated Pickling Effluent Waste Loads

(per ton of steel pickled)

	Best Practicable			Best Available		
	Carbon	Stainless	Alloy	Carbon	Stainless	Alloy
H_2SO_4 NPL						
vol., gals.	23.4	18.5	14.9	0	0	0
Iron, #Fe	0.0008	0.0006	0.0005	-	-	-
lbs., $CaSO_4$	0.39	0.31	0.25	-	-	-
pH	9.0	9.0	9.0	-	-	-
Suspended Solids, #	0.003	0.002	0.002	-	-	-
HCl WPL						
vol., gals.	41.0	53.0	37.2	0	0	0
Iron, #Fe	0.001	0.002	0.001	-	-	-
lbs., $CaCl_2$	0.17	0.22	0.15	-	-	-
pH	9.0	9.0	9.0	-	-	-
Suspended Solids, #	0.004	0.008	0.008	-	-	-
HNO_3 - HF WPL						
vol., gals.	-	67.5	33.8	-	67.5	33.8
Iron, #Fe	-	0.002	0.001	-	0.002	0.001
pH	-	9.0	9.0	-	9.0	9.0
lbs., CaF	-	0.011	0.006	-	0.011	0.006
lbs., $Ca(NO_3)_2$	-	265	133	-	265	133
Suspended Solids	-	0.008	0.004	-	0.008	0.004
H_2SO_4 Rinsewater						
vol., gals.	500	395	318	500	395	318
Iron, #Fe	0.017	0.013	0.011	0.017	0.013	0.011
lbs., $CaSO_4$	7.8	3.2	3.5	7.8	3.2	3.5
pH	6.9	6.9	6.9	6.9	6.9	6.9
Suspended Solids, #	0.06	0.05	0.04	0.06	0.05	0.04
HCl Rinsewater						
vol., gals.	3.8	411	282	318	411	282
Iron, #Fe	0.011	0.014	0.009	0.011	0.014	0.009
lbs., $CaCl_2$	2.1	2.2	1.6	2.1	2.2	1.6
pH	6.9	6.9	6.9	6.9	6.9	6.9
Suspended Solids	0.04	0.05	0.04	0.06	0.05	0.04
HNO_3 - HF Rinsewater						
vol., gals.	-	523	262	-	523	262
Iron, #Fe	-	0.017	0.009	-	0.017	0.009
pH	-	6.9	6.9	-	6.9	6.9
lbs., CaF_2	-	0.09	0.04	-	0.09	0.04
lbs., $Ca(NO_3)_2$	-	2.33	1.16	-	2.33	1.16
Suspended Solids #	-	0.07	0.03	-	0.07	0.03

Cold Reduction

Cold rolling of steel strip is divided into two categories, the cold reduction mill and the temper pass or skin pass mill. Of those operations in the cold reduction category, we may further divide them into the tamden four high mills, the single stand four high reversing mills and also the specialty mills. The principal cold reduced flat rolled products are flat bars, cold rolled strip, cold rolled sheets and black plate. Excluding black plate, the products may be made from any of the main three classifications of steel. The four and five stand tandem cold mills are generally used for high volume sheet and tinplate products while the single stand reversing mill is more normally associated with small production facilities. In the cold reduction process, a coil often being pickled to remove the scale is reduced between 25% and 99% of the hot rolled thickness by one of the above operations. Cold reduction generates heat that is dissipated by flood lubrication in which palm oil or synthetic oils are emulsified in water and directed in jet against the rolls and the steel surface during rolling. Another system involves the application of water to the mill rolls as the cooling medium and direct application of atomized palm oil to the strip as the lubricant. At the final stand a cleaning agent may be applied to remove the rolling oils. After cleaning and annealing the product will generally pass through the "temper pass or skin pass" which only reduces the thickness a few percent but imparts the desired mechanical and surface characteristics.

Treatment of Cold-Mill Wastewater

The wastewater effluents from cold reduction rolling mills contain concentrations of emulsified oil and suspended solids. In addition, a detergent is often used at the final stand to remove all traces of oil from the sheet. Oils used may be of mineral, animal or vegetable origin, soluble or insoluble, and may be found in the wastewater in different degrees of being free or emulsified and saponified or unsaponified. Depending upon the nature of the product being rolled, lubrication and cooling may be applied either on a once through basis or recycled. However, even with a recycle system, batch dumps will occur when the quality of the solution fall below minimum requirements. For example, a 10,000 gallon solution is dumped every seven-ten day period at the five stand tandem mill facility of Midwest Steel Division of National Steel Corporation.

An example of both systems is the Weirton Steel Division of National Steel Corporation. At this plant the rolling solution are recycled at No. 6 & 7 tandem mill and periodically dumped while a once through system is utilized at No. 5 & 8 tandem mill. In both cases the wastewater is pumped to a treatment plant operated by a private firm. Here the wastes are subjected to treatment including chemical additions, air flotation, sedimentation and skimming. The recovered oil may either be returned to the plant for other uses or hauled away.

Various Types of Roll Coolants

Stable Soluble Oil is composed of a mineral base oil and emulsifiers so that a stable water-oil emulsion results. The oil is mixed in a 5 to 12 percent ratio of oil to water and should be recirculated to maintain proper consistency. Soluble oil coolants are used on mills producing sheet steel, silicon steel, and stainless steel.

Unstable Solutions refers to a coolant made up of animal or vegetable fat with little or no emulsifiers. The rolling oil is mixed with water in a 2 to 10 percent ratio of lubricant to water and operated at temperatures between 140° and 160"F. Mechanical agitation is necessary to maintain dispension of the lubricant. This type of roll coolant is used on five and six-stand tandem mills producing black plate for tinplate use.

Meta-Stable Solution is an animal or vegetable fat base lubricant with some emulsifiers. The oil is mixed with water at a ratio of 5 to 10 percent and must be agitated continuously. The stability of this coolant lies between the stable and unstable solutions and is used at temperatures between 120-140° F. This type of coolant finds the majority of its use on double reduced tinplate mills and high-speed tandem mills for sheet rolling.

COLD REDUCTION RAW WASTE LOADS

Water use on cold reduction mills was given as from 1,675 to 3,000 gallons per ton in the 1967 Profile. The NUS report gives an average value of 1,700 gallons per ton. A water use of 10,000 gpm for a modern 5-five tandem mill is given by both Bowman and Houston (A.I.S.E. Yearbook, 1966) and Gronbech (Management of Water in the Iron and Steel Industry, A.I.S.I., London). The 5-stand tandem mills at Weirton Steel in Weirton have capacities of 600,000 and 660,000 tons annually. A similar mill at J & L's Aliquippa works has a capacity of 637,200 annual tons and one at Armco's Ashland Works has a capacity of 720,000 tons per year. At an average of say 650,000 tons per year, a water use of about 8,000 gallons per ton is indicated, or about 1,600 gallons per ton per stand.

The 1967 Profile gives oil and solids concentrations at 150 ppm and 50 ppm, respectively, in the effluent. The NUS report gives ranges of 5-185 ppm suspended solids and 15-1500 ppm oil, with averages of 125 ppm and 300 ppm, respectively. Other reported concentrations areas follow in cases where varying degrees of coolant recirculation are practiced:

Plant	Oil, ppm	Solids, ppm
J & L, Hennepin Works	200	50
Bethlehem, Lackawanna	230	100
National Steel, Midwest	200	-
National Steel, Weirton	376	111 (1)

---

(1) Total iron

The most reasonable values from the above appear to be 100 ppm suspended solids and 200 ppm oil. Assuming recirculation of the coolant solution with discharge only from the final stands as the base conditions, raw waste loads are 1.33 lbs. solids and 2.67 lbs. oil per ton of steel in an effluent volume of 1,600 gallons per ton of steel. The spent emulsions are additionally dumped on a batch basis. Recovery of most of the oil in the spent emulsions has long been practiced; recovery plants are operated in many steel mills on a contract basis by such independent companies as Palm Oil Recovery, Inc. who process the oil for sale.

On the basis of the data from Armco at Ashland Works, the concentrated coolant amounts to about 11.1 gallons per ton of steel and has the following composition:

Suspended Solids	1025 ppm
COD	31600 ppm
Total Oil	14600 ppm
Emulsified Oil	3494 ppm

The contribution to the Raw Waste Load is as follows, and the total Raw Waste Load is calculated below on the basis of the same % total and emulsified oil in the rinsewater as in the concentrated coolant with COD in proportion to total oil:

	Raw Waste Loads, lbs. per ton of Steel		
	Coolant	Rinsewater	Total
Volume, gal./ton	11.1	1600	1611
Suspended Solids	0.09	1.33	1.42
COD	2.91	5.78	8.69
Total Oil	1.34	2.67	4.01
Emulsified Oil	0.32	0.64	0.96

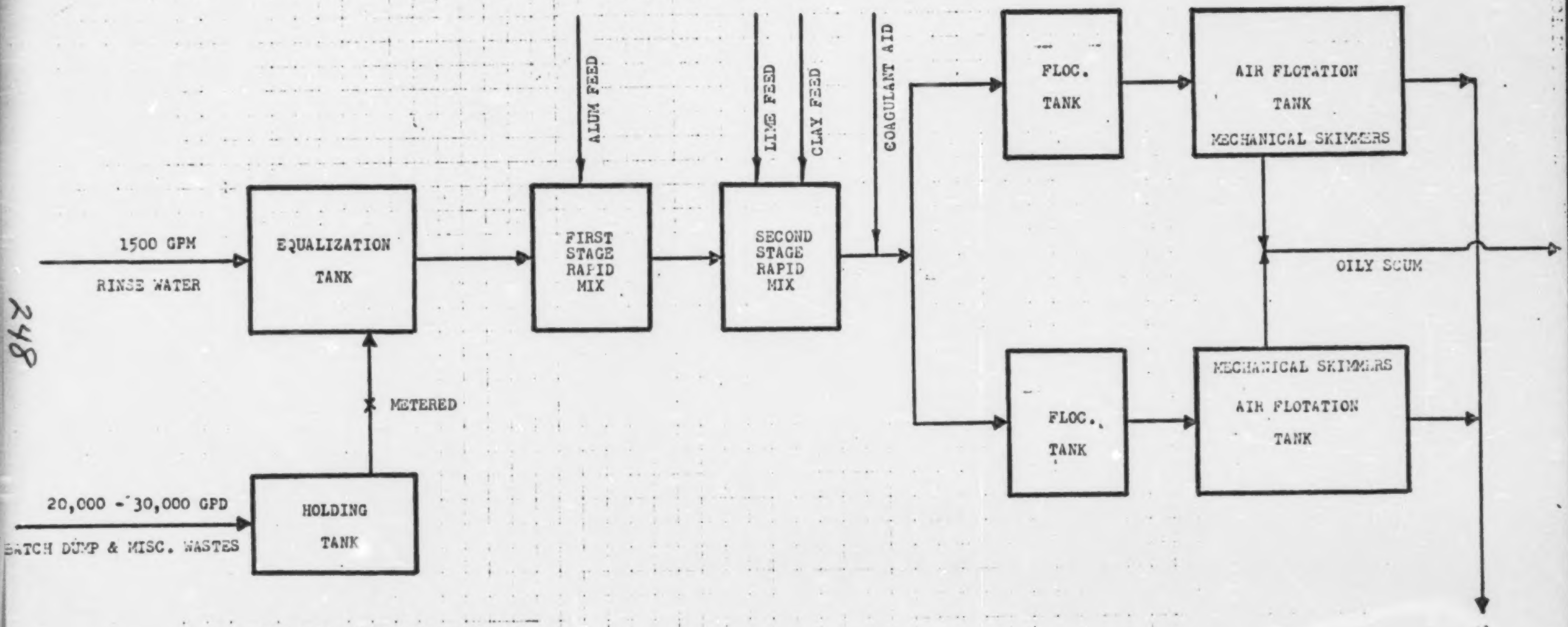
The best practicable treatment probably corresponds to the demonstration program results at Ashland. During the test period, average results were reported as follows in an effluent of 350 gpm. resulting from the treatment of combined rinsewater and coolant.

pH	6.0-7.6
Turbidity, JTU	37
COD, ppm	441
BOD, ppm	57
Total Oil, ppm	76
Suspended Solids, ppm	51

The effluent load then in 1611 gallon per ton would be not more than as follows with treatment similar to the Armco system at Ashland shown in Figure 26 . Somewhat lower loads are probable on the basis of the few operating data available when the coolant/rinsewater ratio approximated 11/1600.

FIGURE 26

FIVE STAND TANDEM COLD MILL - ARMCO STEEL CORPORATION, ASHLAND KENTUCKY



INFLUENT ANALYTICAL DATA

ANALYSIS	CONCENTRATION AVERAGE	CONCENTRATION RANGE
SUS. SOLIDS	80	16-280
C.O.D.	5556	1040-37600
TOTAL OIL	895	113-3034
EMUL. OIL	244	30-850
B.O.D.	383	165-540
pH		6.2-8.1

Best Practicable Effluent Loads (per ton of steel)

Volume	1611 gallons
COD	5.92 lbs.
BOD	0.76 lbs.
Total Oil	1.02 lbs.
Suspended Solids	0.68 lbs.

The best available treatment should correspond to the batch treatment of coolant with recirculation on all stands, i.e., the effluent is concentrated coolant only. On the basis of the Armco data, the effluent loads would be:

Parameter	Raw Load, #/ton	% Removal	Effluent Load # Ton
Volume, gallons	11	--	11
Suspended Solids	0.09	74	0.02
COD	2.91	92	0.23
Total Oil	1.34	95	0.07
Emulsified Oil	0.32	95	0.02

Intermediate between these levels of treatment would be that corresponding to the Armco rinsewater treatment scheme in which 2,360,000 gallons of wastewater was generated in rolling 9,000 tons of steel. The effluent waste loads would thus be:

Parameter	Effluent	Waste Load, #/ton
Volume	262 gal.	262 gal.
COD	441 ppm	0.96 #
BOD	57 ppm	0.12 #
Total Oil	76 ppm	0.17 #
Suspended Solids	51 ppm	0.11 #

The capital costs for treatment are probably best estimated on the basis of the Armco data for the rinsewater system, accepting the Armco statement that the rinsewater system would be built as a standby for future operational changes.

$$\frac{\$\,1,070,000}{780,000 \text{ tons/yr.}} = \$1.37 \text{ per annual ton}$$

Operating costs for the intermediate level of treatment above are about $0.06 per ton of steel rolled, and should be about the same for the Best Practicable Treatment. Operating costs for the Best Available Treatment are about $0.07 per ton of steel rolled.

TEMPER AND SKIN PASS MILLS

After the cold rolled strip has been cleaned and annealed, the final mechanical properties are developed by the temper or skin pass mills. The principal purpose of this process is to acquire the proper stiffness or hardness by cold working the strip. Additionally, tempering tends to improve the flatness of annealed strip which is of great importance. Most modern temper mills utilize heavy coils and operate at high speed. From a Report published in the Water Pollution Control Research Series, the following discharge data was acquired.

Discharge from Temper Mill
(Flow: 2,880,000 gpd)

Parameter	High	Low	Average
pH	9.4	8.6	9.1
PHL Alkalinity, mg/l	140	6	70
M. O. Alkalinity, mg/l	200	32	96
Hexavalent Chrome, mg/l	0.1	0	0.03
Total Chrome, mg/l	0.2	0.1	0.10
Suspended Solids, mg/l	40	25	33
Oils, mg/l	58	14	31

Since temper passing is performed dry, wastewater results from machine cooling water. The major pollution parameter from this process is oils used as lubricants for the equipment.

ELECTROLYTIC TIN PLATING

Since electrolytic tin plating is superior to hot-dipped tin plate, about 96% of all tin plating in the United States is produced by the electrolytic process. Prior to 1940, all commercial tin plate was produced by the hot dip process. The major types of electrolytic tin plate lines are listed below with estimated capacities.

Horizontal Acid, Halogen or Weirton line	250,000 tons/yr.
Vertical or Ferrostan Lines	150,000 tons/yr.
Alkaline Solution or Alkaline Lines	150,000 tons/yr.

Aside from the difference, such as plating solutions, current densities, and physical arrangements, the following process steps generally apply.

1. Electrolytic cleaning in alkaline solutions. This step removes those contaminates resulting from prior processing particularly regarding oil and dirt.
2. Rinsing.
   Water sprays remove carryover from prior cleaning in alkaline solution.
3. Pickling.
   Removal of iron oxides
4. Rinsing.
   Water sprays remove carryover from prior pickling
5. Plating.
   Solutions, number of cells, and sizes vary according to type of process

6. Recovery Tank, Hot Rinse Tank, Drier, and Melting Zone.
   In this stage, the tin coating evolves from a matte form to the mirror-like finish.
7. Chemical Treatment
   In a chromate solution, tin oxides are removed and the tin surface is given a resistance to oxidation.
8. Oiling
   During this step, oil is normally applied electrostaticly. Stabilized cottonseed oil or synthetic dioctyl sebacate may be used.

Tin coating by the electrolytic process can range from 0.10 lbs./BB and up. As an example a coating of 11 lbs/BB will produce a coating thickness of 0.000060 inches.

1. Fresh Pickle Liquor
2. Raw Waste Loads
   a. Continuous
   b. Batch
3. Strong Spent Liquor
   a. Air-oxidation neutralization
   b. Regeneration
      i. HCl - Dravo-Ruthner
      ii. H_2SO_4 Higgins Williputte Blaw-Knox Ruthner Fitzsimmons
4. Rinsewater
   a. Limestone neutralization

Chrome Plated Steel

With the development of means to join containers by methods other than soldering and with the rapid increase in the price of tin, the chrome plated-tin free steel market has emerged. Chrome plated steel has been successfully used in applications which involve 40 percent of a 67,000,000,000 can market, or over 2,000,000 tons annually in the United States. In figure 27 a typical chrome plating operation is illustrated, showing in detail each major stage of operation involving water. Because of the similarity of chrome plating to tin plating, it would be expected that some present tin lines will be converted to chrome, rather than the construction of new facilities. Both National Steel at Weirton, W. Va. and Bethlehem Steel at Sparrows Point, Md. have completed such conversions. Wastewaters generated within the chrome plating process may be divided into two separate types; (1) Rinse water (2) Concentrated process solutions. At the Sparrows Point plant a system was devised to reuse the rinse water by taking clean, heated water (from the plater and chemical treatment heat exchangers) and use it successively in the final rinse, and previous chemical treatment stage rinses, exactly reverse of the strip processing. Together with a similar system applied to the plating stage rinses, the reused rinse water is collected in a reserve tank and pumped through a strainer to remove particulate matter, a cation exchanger to remove iron, and then into the evaporation loop. This system thus eliminates discharge of chrome bearing wastewater and recovers the valuable concentrated chromium solution for reuse in the plating process. Drag out from the concentrated plating and chemical treatment may be collected in the reserve tank along with the rinse water. This system was chosen over the traditional method of adding Barium Carbonate to the chromic acid solution to precipitate a sludge of Barium Chromate for both economic and environmental reasons.

FIGURE 27

PRODUCTION STAGES OF A TIN FREE STEEL- CHROME PLATE LINE

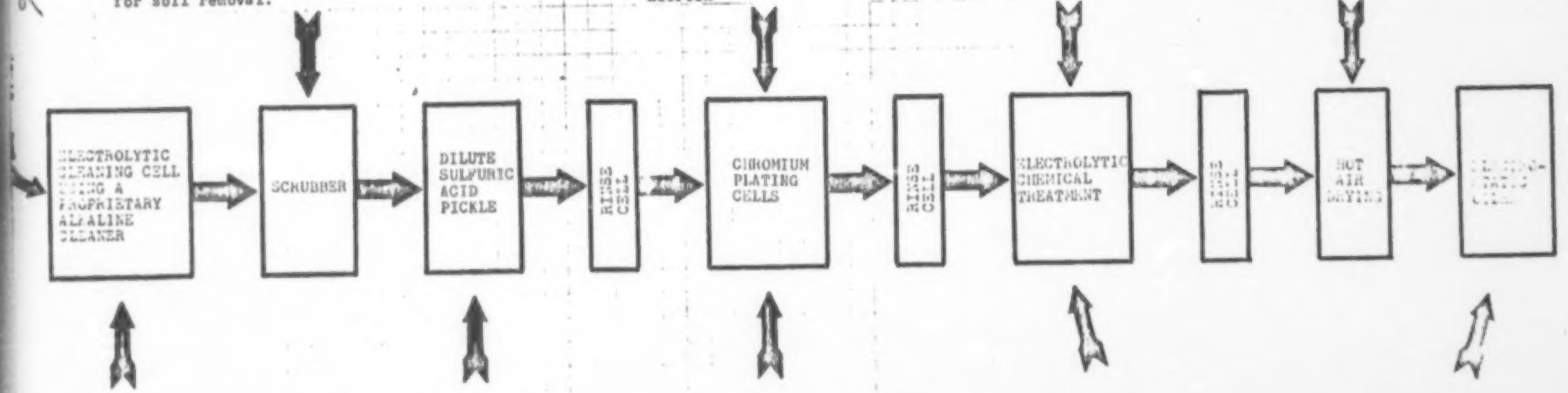
LINE SPEED 1000 TO 1600 FPM

Scrubber rinse water may be slightly acidified to neutralize alkali carry over, heated to provide better solubility for soil removal.

The metallic chromium plating has a nominal thickness of 0.1 to 0.5 microin

The chemical treatment or chromium oxide coating is about 1 to 4 mg per sq. ft. of surface

Hot air drying prepares the strip for the application of an oil film approximately 0.2 mg per sq. ft. of surface


ELECTROLYTIC CLEANING CELL USING A PROPRIETARY ALKALINE CLEANER
SCRUBBER
DILUTE SULFURIC ACID PICKLE
RINSE CELL
CHROMIUM PLATING CELLS
RINSE CELL
ELECTROLYTIC CHEMICAL TREATMENT
HOT AIR DRYING

xample- a 4-oz. per gallon
lution consisting of a
xture of Sodium Hydroxide,
risodium Phosphate and a
rfactant.

Example- a three to five percent solution of Sulfuric Acid at a temperature of about 140 F.

Example- plating solution strength
Chromic Acid
130 to 275 gm per liter
Sulfuric Acid
0.8 to 2.2 gm per liter
Temperature
120 to 125 F
Current Density
500 to 1000 amp per sq. ft.

Example- proprietary compositions with a Chromic Acid and Sulfuric Acid base used at temperatures of 125 to 130 F.

Example- the strip is oiled electrostatically with Dioctyl Sebacate (DOS)

The raw waste loads for tinplating and chrome plating are best estimated from the Weirton Steel Company data. The 4 tin mills there have a combined capacity of 1135 tons per turn, or 3,405 tons per day. The chrome plating line operates at 1,500 ft./min. as compared with the tin lines at 1,800 ft./min. Chrome -lating capacity is thus about 709 tons/day. The total plating capacity is 4,114 tons per day and the total effluent is 15,000,000 gpd, equivalent to 3,646 gallons per ton. This plant includes 2 continuous annealing lines, a water demineralization plant, and 2 so-called Weirlite mills which function to further reduce strip thickness prior to plating. Average effluent analyses are as follow:

Parameter	Tin Lines 4	Tin Lines 5	Tin Lines 6	Average Tin Line	Tin Line & Chrome Line	Calculated Chrome Lin
pH	6.40	4.60	3.90	4.60	6.70	± 8.8
Chloride ppm	39.10	207.00	45.5	97.2	111.00	124.8
Sulfate ppm	104.60	152.00	250.7	169.1	130.50	91.9
S.S. ppm	80.20	129.10	146.0	118.4	457.50	797
Total Fe ppm	4.40	21.60	29.0	18.3	30.60	42.9
Total Cr ppm	20.20	15.50	2.1	12.6	49.00	85.4
Hex Cr ppm	10.40	0.34	0.0	3.58	5.50	7.42
CN ppm	0.74	1.06	1.04	0.95	0.15	--
Tin ppm	48.90	122.90	12.4	61.4	--	--
Fluoride ppm	27.00	30.48	8.6	22.0	--	--

The average plating line at Weirton has an effluent of 2.56 mgd, equivalent to 3,000 gallons per ton, which is the appropriate volume to use with the above concentrations to calculate raw waste loads.

	Raw Waste Loads, #/ton Plated	
Constituent	Tin Plating	Chrome Plating
pH	6.7	8.8
Chloride	2.43	3.12
Sulfate	4.23	2.30
Suspended Solids	2.96	19.9
Total Iron	0.46	1.07
Total Chromium	0.32	2.14
Hex. Chromium	0.09	0.19
Cyanide	0.02	--
Tin	1.54	--
Fluoride	0.55	--

Detinning Facilities

The principal function of a detinning plant is to recover for reuse metallic tin from both tinplate scrap and electrolytic sodium fluorostannate acid sludge. In the detinning operation tin bearing scrap is rotated in a tank containing sodium nitrate and caustic soda at temperatures of about 205°F until the solution absorbs sodium stannate. Excess sodium stannate precipitates out of solution and settles on the bottom.

The detinned scrap is returned to the steelmaking facilities and the sodium stannate precipitate is subjected to a sulfuric acid treatment which converts it to stannic hydroxide. The stannic hydroxide is then filtered, dried, mixed with anthracite coal and reduced to metallic tin. The electrolytic sodium fluorostannate acid sludge is reacted with sodium carbonate to form stannic hydroxide and treated in the same manner as above wastewaters in the detinning operation evolve from filtering, rinsing and spills. Wastewaters from the detinning scrap operation may amount to 280 gallon per ton of scrap processed. Pollutant levels for such an operation are shown below.

	Concentration, ppm			Wasteload
Parameter	High	Low	Average	#/ton of scrap
pH	9.3	7.8	9.0	--
Pht Alkalinity	352.0	4.0	108.5	0.4254
M.O. Alkalinity	1072.0	64.0	540.6	2.1200
Chlorides	422.0	24.0	128.1	0.5023
Sulfates	6996.0	110.4	1490.5	5.8450
Suspended Solids	2397.0	64.5	390.8	1.5325
Total Iron	14.2	3.7	6.9	0.0270
Cyanide	0.96	0.46	0.73	0.0028
Tin	1440.0	9.7	191.5	0.7509
Total Chrome	0.15	0	0.06	0.0002

Wastewater from the detinning sludge operation may amount to 9 gallon per ton of tin plate product. Pollutant levels for such an operation are shown below:

Parameter	Concentration, ppm			Wasteload
	High	Low	Average	#/ton of tin plate
pH	10.9	7.1	8.6	--
M.O. Alkalinity	3850.0	76.0	1932.0	0.1361
Chlorides	275.0	50.0	135.8	0.0095
Sulfates	14400.0	1080.0	5580.0	0.3932
Suspended Solids	1287.0	90.0	633.0	0.0446
Total Iron	36.6	2.0	13.3	0.0009
Total Chrome	6.4	0	1.8	0.0001
Fluorides	920.0	430.0	571.2	0.0402
Tin	540.0	24.8	137.8	0.0097
Cyanide	6.5	0.13	3.3	0.0002

Additional pollution parameters which may exist in the discharge are nitrates and dissolved solids.

Galvanizing

Total galvanizing capacity in the United States is estimated at 6,400,000 net tons per year[1] In 1971, shipments of galvanized sheet and strip amounted to 5,067,609 net tons or 5.82% of total net shipments. Of the total galvanized shipments, 4,742,493 net ton or 93.6% of total shipments were produced by the hot-dip method while 325,115 net tons or 6.4% of the total were produced by the electroplating process. With the exception of 4,707 net tons of galvanized shipments being alloy steel, all other shipments were carbon grade.

In 1961, 368,773 tons of slab zinc were consumed by the galvanizing industry. Of this amount, 209,606 tons were used for the galvanizing of 3,330,000 net tons of sheet and strip or 125.9 lbs. of zinc per ton of product. Assuming the same proportion for 1971, it would require 319,006 tons of slab zinc for galvanizing.

In the hot-dip process, a zinc coating is applied by passing the material through a molten bath of the metal. Several designs of continuous hot-dip galvanizing lines are in commercial use and indicated below.

---

1. "Developments in the Iron & Steel Industry During 1970", Iron and Steel Engineer Year Book

1. The Cook-Norteman Process

   This process takes strip that has been annealed separately, cleans the surface by chemical means and then applies a zinc-ammonium-chloride flux prior to the zinc bath.

2. The Sendzimir Process

   Uses the advantages of continuous pretreatment and annealing with the aluminum in the zinc bath.

3. The United States Steel Corporation Process

   Rolling oil residues are removed by anodic cleaning, followed by annealing and cooling in an atmosphere of cracked ammonia.

4. The Weirton Steel Company Process

   Batch annealed strip is precleaned by chemical methods and preheated in a reducing atmosphere prior to the zinc bath.

5. The Sharon Steel Corporation Process

   To clean the strip prior to galvanizing, gaseous hydrogen chloride is used at temperatures where iron chloride is volatilized.

Zinc coatings are electroplated from two types of solutions, the acid bath and the alkaline cyanide bath. The acid bath process is widely used for coating strip and wire while the alkaline cyanide process may be more generally applicable for coating hardware, iron and steel castings, and small manufactured parts. Steel strip widths up to 60 inches are electrogalvanized with coating as low as .015 to .020 oz./square foot. Because of the very thin coating several proprietary phosphates are used for corrosion protection and paint bonding characteristic. Preparation of the base metal is very important, thus great care is extended to provide a clean surface for coating. Normally alkaline cleaning bath, made up of mixtures of sodium hydroxide, sodium carbonate, phosphates and silicates, are used to remove oil and grease, followed by acid baths of sufficient strength to remove oxide films. The acid baths would normally contain either a solution of sulfuric acid, 5 to 10% by weight or hydrochloric acid, 20% by weight. During 1970 only one new galvanizing line went into operation, the 72" continuous galvanizing line at the Midwest Steel Division of National Steel Corporation. This line is designed to have an optimum capacity of 60 tons per hour while producing 18 gauge by 42 inch wide product with a maximum capacity of 100 tons per hour on the full hard cycle steel.

The galvanizing department of the Weirton Steel Division of National Steel Corporation consists of four continuous galvanizing lines. Wastewaters from the galvanizing operation consist primarily of orthosil tank overflow, scrubber waters and rinses. Total discharge from all four lines is about 4,320,000 gallons per day. Examples of the discharges are reported in the publication entitled "Combined Steel Mill and Municipal Wastewater Treatment".

Total Galvanizing Department Discharge
Flow- 4,320,000 gpd

	Concentration, ppm			
	High	Low	Average	#/ton galvanized
pH	10.2	2.9	8.9	--
Pht. Alkalinity	62	10	27.6	0.62
M.O. Alkalinity	104	42	65.8	1.48
Mineral Acidity	--	--	118	2.65
Total Iron	25.5	4.8	17.1	0.38
Chlorides	48	20	32.5	0.73
Suspended Solids	218	99	198.5	4.47
Phosphates	6.4	1.2	4.3	0.097
Silicon	20.9	13.8	17.9	0.38
Zinc	1.1	0.31	0.6	0.014
Total Chrome	3.3	0.56	1.5	0.030
Hexavalent Chrome	2.9	0.42	1.0	0.023

Volume = 2,700 gallons per ton

The above values may be taken as the best available data on raw waste loads from hot-dip galvanizing. Electrogalvanizing in the steel industry utilizes the acid process so that cyanides are not a problem from this source. The only information on electrogalvanizing wastes is in U. N. Data which indicates 100 ppm zinc in 113-150 tons per day of rinsewater in a plant galvanizing 10,000 tons per year. The indicated raw waste loads are thus 1,098 gallons of rinsewater and 0.91 bls. of zinc per ton electrogalvanized.

The treatment methods demonstrably available for wastewaters from tin or chrome plating, electrogalvanizing, and galvanizing are chromate reduction, sedimentation with chemical flocculation, and rinsewater reuse. The effluent concentrations to be expected may be as good as though reported for the galvanizing operation at H. H. Robertson Company, Ambridge, Pennsylvania as follows:

pH	7.82
Suspended Solids	5 ppm
Dissolved Iron	0
Manganese	0.01 ppm
Total Zinc	0.3 ppm
Total Chromium	0.07 ppm
Oil	0.1 ppm

In an average wastewater volume of 3,000 gallons per ton, the corresponding loads would be:

Suspended Solids	0.05 ppm
Dissolved Iron	0
Manganese	.0003 ppm
Total Zinc	.008 ppm
Total Chromium	.002 ppm
Oil	.003 ppm

While these values have been attained at this relatively small plant in a new treatment facility, they are probably excessively stringent for general application. A comparison is made below between the above data and the "A" level treatment standards proposed by AISI.

	Concentration, ppm		
Parameter	A.I.S.I. Tin Plating	A.I.S.I. Other Coating	H. H. Robertson
Suspended Solids	15.6	15	5
Dissolved Solids	1.17	1.2	0
Manganese	-	-	0.01
Total Zinc	-	1.2	0.3
Total Chromium	0.7	0.05	0.07
Oil	-	-	0.01
Tin	7.0	-	-
Cyanide	0.78	0.18	-

The most reasonable values would appear to be averages of the above concentrations with the value for tin based upon the tin/chromium ratio as indicated by the A.I.S.I. tin plating data and oil equal to the best observed in rolling mill operations. Best practicable treatment is based upon the use of 3,000 gallons per ton and best available treatment upon a reuse factor of 50%; the latter seems to be conservative in view of H. H. Robertson's reuse of 80%.

Constituent	Concentration, ppm	Best Practicable Treatment, #/ton	Best Available Treatment/#/ton
Suspended Solids	10	0.250	0.125
Dissolved Iron	0.6	0.015	0.008
Manganese	0.2	0.005	0.003
Total Zinc	0.7	0.018	0.009
Total Chromium	0.3	0.008	0.004
Oil	5	0.125	0.063
Tin	3.0	0.075	0.038
Cyanide	0.40	0.010	0.005

The treatment costs for steel coating wastewaters should be approximately the same as for pickling rinsewater, i.e., $630 per 1,000 gpd capital costs and $0.24 per 1,000 gallon operating costs. On the basis of the typical line at Weirton, capital costs are:

823 tons/day x 3646 gals/ton x $0.630/gpd = $1,890,415

= $2297/daily ton = $6.29/annual ton

At 3,000 gal./ton operating costs equal $0.08 per ton.